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Inland Waters Directorate
Western and Northern Region

Direction générale des eaux intérieures
Région de l'Ouest et du Nord

WATER QUALITY IN THE CUMBERLAND MARSHES

1979 - 1984

MAIN REPORT

JUNE, 1985

PREPARED FOR THE PRAIRIE PROVINCES WATER BOARD BY:

R. W. CROSLEY

ENVIRONMENT CANADA

INLAND WATERS DIRECTORATE

WATER QUALITY BRANCH

WESTERN AND NORTHERN REGION

REGINA, SASKATCHEWAN

WQB - W&NR - 85 - 03

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TO: COMMITTEE ON WATER QUALITY MEMBERS

SUBJECT: CUMBERLAND MARSHES WATER QUALITY REPORT

In accordance with the COWQ request for Environment Canada to interpret the results of water quality monitoring in the Cumberland Marshes Project area, I have provided herewith the Water Quality Branch's report on this subject for your information and use. The report consists of two volumes: the main report and Appendices.

The main and relevant finding of this report as based on water chemistry, is that the Cumberland Marshes Project does not appear to have any significant detrimental effect on the quality of waters crossing the Saskatchewan-Manitoba boundary nor on downstream water uses. The report concludes that it is not necessary for Environment Canada to continue with the chemistry monitoring program as the needs of the PPWB have now been met. However, monitoring or more comprehensive assessments may be desirable in the future if the PPWB or water management agencies require trend information or re-affirmation of the outflow quality. The 1979-84 data base will serve as a basis against which future water quality can be compared for trend assessments. Changes in Project characteristics may also substantiate future monitoring.

I thank the Committee members for their constructive comments during the draft stage of this report. Also, thanks go to Ducks Unlimited and the Saskatchewan and Manitoba Fisheries Departments for their assistance. I would be remiss if I did not also thank Mr. R. Crosley of the Water Quality Branch who, despite a very tight and revised deadline, still managed to consult with many of you and prepare this report.

I trust that the report meets the expectations of the Committee on Water Quality. Should the Committee require further dialogue on the Cumberland Marshes water quality monitoring program, I would be pleased to oblige.

Yours truly,

Wm. D. Gummer
Chief, Water Quality Branch
Western and Northern Region

WDG/dm

cc: H. Vaughan
R. Crosley

Attach.

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EXECUTIVE SUMMARY

Monitoring of the chemical water quality characteristics of waters diverted into the Ducks Unlimited Cumberland Marshes Project via the Dragline Channel, and of Project releases to the Birch River, was conducted during the period 1979 to 1984. The Project Area, located in Saskatchewan adjacent to the Manitoba boundary, gave rise to transboundary water quality concerns, as Project water releases, depending on quality, could potentially affect the use of waters downstream in Manitoba. It was in this context that the Water Quality Branch of Environment Canada, at the request of the Prairie Provinces Water Board, and with the cooperation of Saskatchewan Environment and Ducks Unlimited (Canada), undertook water quality monitoring.

The inflowing and outflowing waters of the Cumberland Marshes Project Area differed in a number of chemical characteristics. Concentrations of most major ions and nutrients were higher in the outflowing waters. Differing orders of abundance of major ions in the inflow and outflow indicated that groundwater intrusion in the Cumberland Marshes may be significant. The Birch River displayed characteristics consistent with winter anoxia, such as increased winter concentrations of iron, manganese, and phosphorous. Marshes produce winter anoxic conditions due to the substantial oxygen demand created by plant growth/decay cycles. Nutrient export from marsh systems reflects the ability of plants to capture atmospheric carbon and nitrogen. It was thought that the differing chemical quality of the inflowing and outflowing waters were due in most part to natural effects.

Concentrations of chemical constituents potentially affecting fish stocks were, with the exception of iron and dissolved oxygen, acceptable for the protection of aquatic life, according to criteria proposed by the United States Environmental Protection Agency. While winter concentrations of iron were above the recommended criterion concentration, most of the iron was probably bound to humic and fulvic acids and, therefore, biologically unavailable.

Dissolved oxygen concentrations at the Birch River monitoring location were typically near 5 mg/L during winter, due to local open-water reoxygenation. As early as 1966, however, Fisheries personnel reported winter oxygen depletion in most parts of the Cumberland Marshes. This has been confirmed by a number of more recent surveys. Oxygen shortage has resulted and will probably continue to result in local fish kills. A number of mitigative measures have been implemented by Ducks Unlimited (Canada) to protect the local fishery. These measures were designed to increase winter oxygenation in Cut Beaver Lake of the Cumberland Marsh, prevent fish migration downstream from Cut Beaver Lake, and increase fall migration of fish out of Manitoba's Saskeram Marsh. As these steps appear to have been successful in minimizing the number and severity of fish kills in the area, and since it is the view of

Manitoba and Saskatchewan Fisheries personnel that the Dragline-Cut Beaver and Saskeram Marsh fisheries are of sufficient value to warrant protection, the continuance of these measures is considered desirable.

On the basis of chemical constituent concentrations, the waters discharged from the Cumberland Marshes Project appear to be, for the most part, of better quality than the receiving waters of the Carrot River. Therefore, it stands to reason that the Project has had no detrimental chemical-related effects on downstream water uses of the Carrot and Saskatchewan Rivers. If the Project is operated in a similar manner in the future, this assessment is not likely to change, although there remains some question as to whether or not the Project has as yet reached equilibrium.

Should long-term trends in chemical quality require quantification, the data base obtained will provide a basis against which future quality can be compared. Confident identification of trends within the study period was not possible due to the variability created by seasonal and inter-year hydrologic factors.

This report is not the definitive word on Cumberland Marshes Project impacts on interjurisdictional water quality, but it does provide for a better understanding of the chemical quality of the waters monitored and their potential impact on downstream water uses. At the time the monitoring began, concerns related to water chemistry. Hence, the scope of this report is restricted to describing chemical characteristics. However, it should not be inferred that biological changes or effects are of lesser importance. Biological considerations would have to be the subject of further studies, should water resource management agencies require such a knowledge base.

The water quality data collected during 1979 to 1984 adequately characterize baseline chemical conditions during that period, and it is felt that continued water quality monitoring in the Cumberland Marshes is not required at this time. A need for future monitoring may become apparent, however, if major fish kills are observed during forthcoming years, if new construction or other significant Project changes occur, or if new downstream water uses are contemplated. Regardless of whether these future changes or events occur, water managers may consider future monitoring necessary to determine whether or not the Project has reached a stable equilibrium.

The Water Quality Branch, by recommending that monitoring of water quality be suspended, does not wish to imply that this Project should be exempt from ongoing licensing regulation. The responsibility for such regulation rests with the Province of Saskatchewan. If Ducks Unlimited (Canada) wishes to include water quality monitoring as part of its overall water management strategy, the Water Quality Branch will, if requested, provide related assistance and advice.

1.0 INTRODUCTION

Between 1974 and 1980, Ducks Unlimited (Canada) constructed an extensive network of water control works in the Cumberland Marshes area of east-central Saskatchewan near the Saskatchewan-Manitoba border, to improve waterfowl and muskrat habitat in the area. During the construction period, concern was expressed that the Project had the potential to adversely affect the quality of waters crossing the interprovincial boundary. At the request of the Prairie Provinces Water Board, which is responsible for investigating and recommending solutions to interprovincial water problems, monitoring of surface waters above and below the Project Area was initiated by Environment Canada (PPWB Minute 17-08, dated 1977/11/09). Water quantity monitoring began in 1978, and water quality monitoring in 1979. The study was funded and field work carried out by Ducks Unlimited (Canada). Environment Canada has prepared annual reports describing monitoring results and operations of the Marsh for the years 1978 through 1983 inclusive (Environment Canada, 1979, 1980, 1981, 1982, and 1983).

Water quality monitoring was suspended in the fall of 1984, after five years of data had been gathered. The purpose of this report is to assess the water quality data in the context of the original study objectives, and to recommend whether further monitoring is required to meet those objectives.

1.1 Study Objectives

The objectives of the study were:

(i) to characterize the chemical quality of the inflowing and outflowing waters of the Cumberland Marshes watershed;

(ii) to determine the possible effects of the Ducks Unlimited Cumberland Marshes Project on exported waters; and

(iii) to document any water quality trends occurring as the Project reaches equilibrium.

2.0 THE DUCKS UNLIMITED CUMBERLAND MARSHES PROJECT

2.1 History and Description

The Cumberland Marshes Project area is rectangular in shape, with the north and south boundaries being the Old Channel of the Saskatchewan River and Petabec Creek - Birch River, and the west and east boundaries being the Dragline Channel and the Saskatchewan-Manitoba border (Figures 1 to 3). The area is drained

FIGURE 1

DUCKS UNLIMITED
CUMBERLAND
MARSHES PROJECT

PROJECT AREA

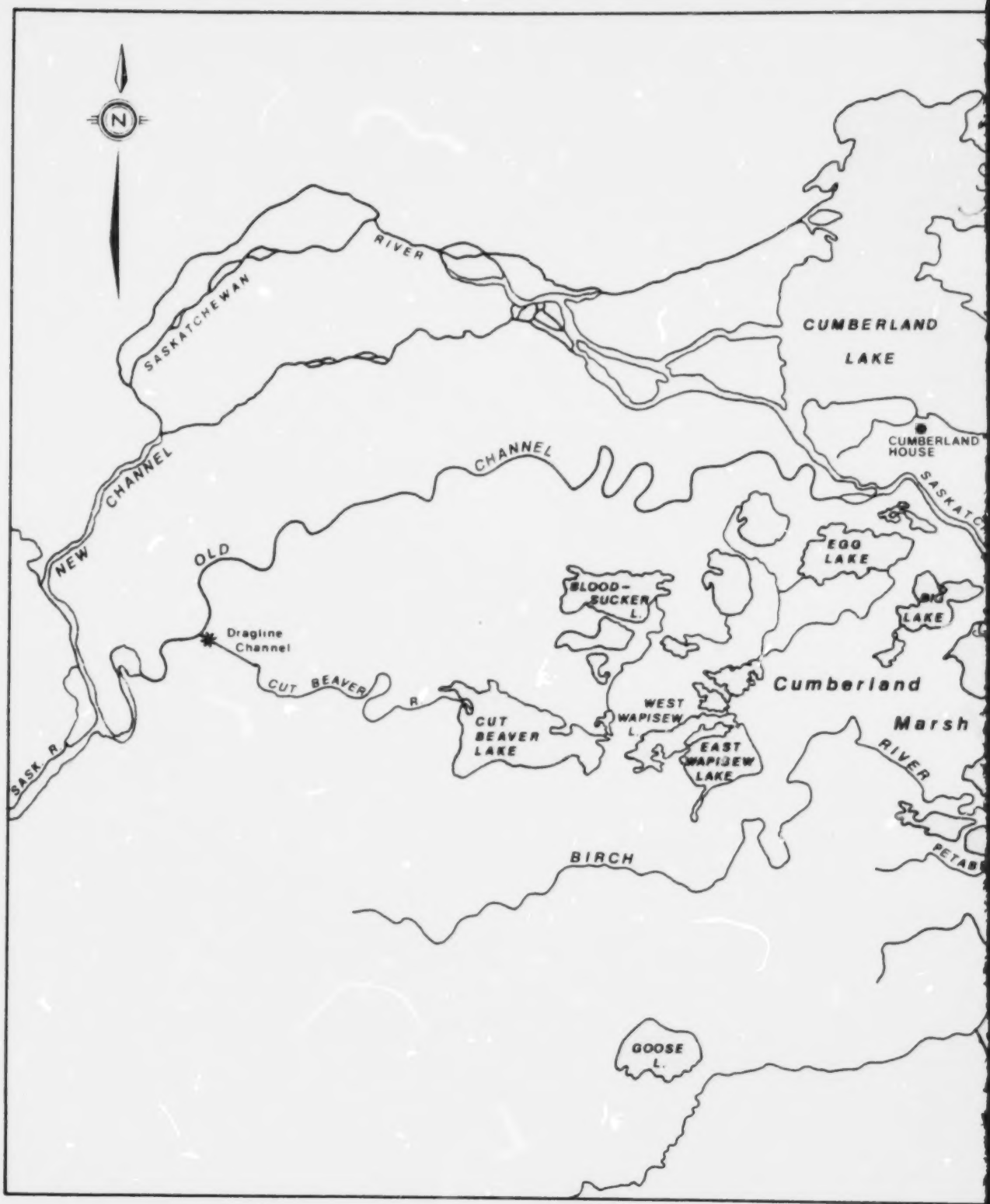
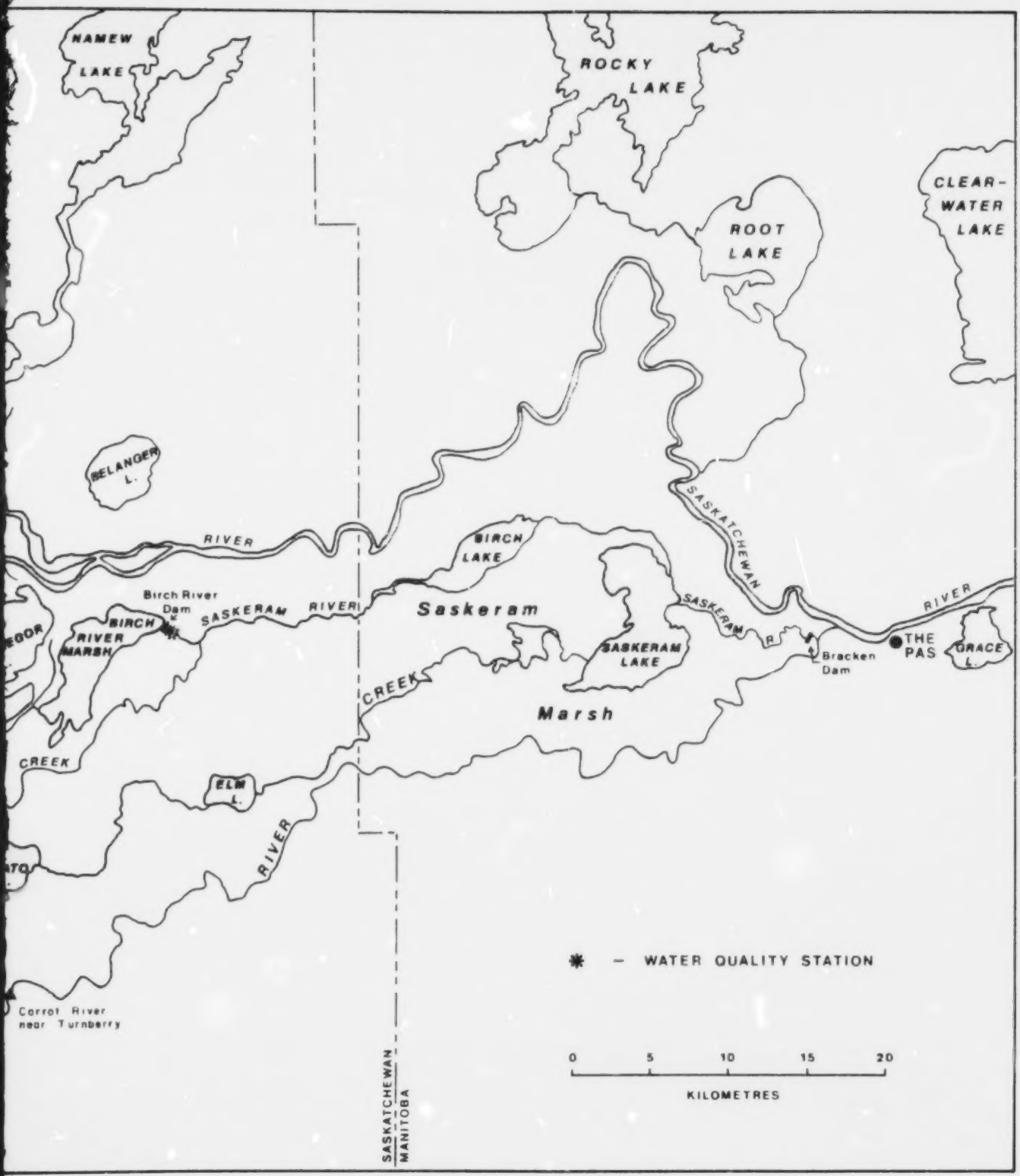
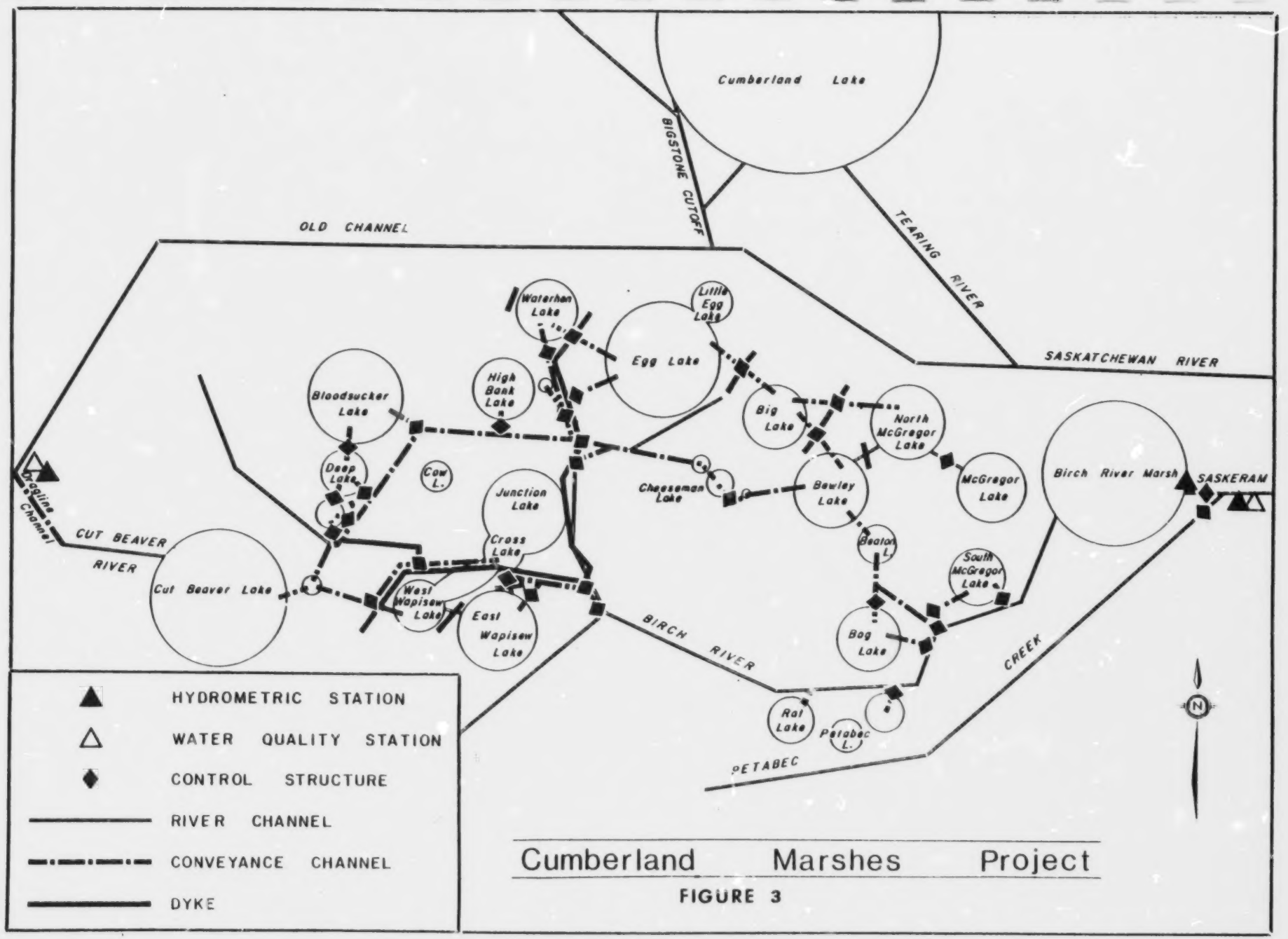


FIGURE 2 CUMBERLAND AND SASKERAM MARSHES


NAMEW LAKE
ROCKY LAKE
CLEAR-WATER LAKE
ROOT LAKE
BELANGER L.
RIVER
BIRCH LAKE
SASKATCHEWAN RIVER
Birch River Dam
SASKERAM RIVER
Saskeram Marsh
BIRCH RIVER MARSH
SASKERAM LAKE
SASKERAM R.
Bracken Dam
THE PAS
GRACE L.
CREEK
CREEK
ELM L.
RIVER
Carrot River near Turnberry
SASKATCHEWAN
MANITOBA
* – WATER QUALITY STATION
0 5 10 15 20
KILOMETRES



Cumberland Marshes Project

FIGURE 3

by the Birch and Saskeram Rivers, which flow into the Carrot River just above the confluence with the Saskatchewan River near the town of The Pas, Manitoba. The Cumberland Marshes occupy approximately 1300 square kilometers, of which approximately 500 square kilometers are directly affected by water management practices. The area lies within a physiographic unit known as the Cumberland Lake Lowland, part of the Manitoba Lowlands Region.

The Cumberland Marshes are separated from the Old Channel of the Saskatchewan River by a levee which parallels the banks of the River. Prior to 1875, water supply in the Cumberland Marshes was augmented by regular ice-jam flooding from the Old Channel, and the area was a prolific muskrat producer. During the spring of 1875, a natural channel modification occurred on the Saskatchewan River, causing the majority of flow to be routed north through Cumberland Lake (Ducks Unlimited (Canada), 1979). Flooding of the Old Channel became infrequent, and the fur productivity of the area decreased greatly. In 1938-39, the Hudson's Bay Company began construction of a conveyance channel from the Old Channel of the Saskatchewan River to the Cut Beaver River to augment water supplies at the western end of the Marshes, and of Timber Dam on the Birch River to hold water in the eastern sector, in an attempt to return muskrat productivity in the Marshes to previous levels.

The 1939 channel, known as the Dragline Channel, became the major water source for the Cumberland Marshes. Waters entering the the Dragline Channel flowed down the Cut Beaver River a distance of 16 kilometers to Cut Beaver Lake. From Cut Beaver Lake waters moved either north-east or east through the Marsh complex. Discharge through the Dragline Channel was controlled by the level of the Old Channel, producing annual cycles of flooding during the spring period, and little or no flow for the remainder of the year. The recurrent spring flooding, together with high, stable summer water levels in the Marsh units, had detrimental effects on waterfowl and muskrat habitat by reducing the amount of emergent shoreline cover, and caused the formation of floating vegetation mats through much of the Marsh. By 1960, a number of factors, including decreased muskrat populations, low fur prices, and the need for improvement to structures, led the Hudson's Bay Company to relinquish their lease in the area.

Ducks Unlimited (Canada) involvement in the Cumberland Marshes began in 1960, with the granting of a 15-year management lease. In 1961, the Cumberland Marshes Dam was constructed on the Birch River, seven miles downstream of the old Timber Dam. The new Dam increased the flooded area in the eastern sector of the Marshes. A control structure was built at the inlet to the Dragline Channel during 1962, allowing regulation of the volume of inflow. During the years to 1975, no further construction took place as Ducks Unlimited (Canada) and a number of federal and provincial agencies investigated the potential of the Marshes. In 1975, Ducks Unlimited (Canada) proposed a major construction program consisting of canals, dykes, and water control structures, and entered into a five-year

construction agreement with the Province of Saskatchewan. The construction phase was largely completed by 1979. In 1980, Ducks Unlimited (Canada) began a 33 year Marsh management agreement with the Province.

Management of the Cumberland Marshes is aimed at increasing waterfowl and furbearer production through the improvement of habitat. The Marsh complex is made up of 19 separate units, with independent unit water management accomplished through a system comprising 60 kilometers of dykes, 90 kilometers of canals, and a total of 68 control structures. Cut Beaver Lake acts as a water supply reservoir for the Project area. Water levels in most marsh units can be altered independently, although some eastern units are operated in series. The original Project plan called for an eight to ten year cycle of marsh drawdown and refill to enhance growth of emergent vegetation. Water levels are not allowed to rise within marsh units before July 15, for the protection of waterfowl nests, and after October 15, for the protection of muskrat dens. Water is supplied to each Marsh unit during the summer period (after July 15) to replace evaporative losses. As well, levels are reduced during the fall to provide capacity for spring runoff.

2.2 Water Management Issues

2.2.1 Fisheries Considerations

The Saskeram Marsh, also known as the Carrot River Triangle, lies immediately east of the Cumberland Marshes and includes the area in Manitoba encompassed by the Saskatchewan and Carrot Rivers. The Saskeram Marsh has been managed to increase waterfowl and muskrat production since the 1940s. The area is drained by the Saskeram River, with headwaters in Saskatchewan at the confluence of the Birch River and Petabec Creek. Bracken Dam, located at the Marsh outlet, was first constructed in 1940 by Ducks Unlimited (Canada) to regulate water levels in the Marsh. The Dam was rebuilt in 1962, with a fish ladder added. Water level adjustments of lakes within the Saskeram Marsh are made possible by a series of control structures and small dams.

Following reconstruction of the Bracken Dam in 1962, the Saskeram Marsh was drained each fall to provide pre-migratory staging areas for geese. The fall discharge caused most fish, which were allowed spring access from the Carrot River through the Bracken Dam, to leave the Marsh prior to freeze-up. This management regime continued until 1978. No winter fish kills were reported during that time period (Derksen, pers. comm.).

In 1978, the water level of Saskeram Marsh was lowered to encourage emergent plant growth in previous open water areas, as management priorities shifted to improving habitat for ducks and muskrat. The Saskeram Marsh was partially reflooded during the fall

of 1979. During the reflooding period, fish from the Cumberland Marshes probably followed the substantial flow and passed over the Cumberland Marshes Dam. It is likely that the majority of these fish were winterkilled during the winter of 1979/80, although no observations were reported (Derksen, pers. comm.).

Fish had entry by the Bracken Dam fish ladder during the spring of 1980. During the operating season, substantial flows were once again passed from the Cumberland Marshes to complete the reflooding of Saskeram Lake. To maintain optimum water levels, the Bracken Dam and fish ladder were closed during the fall of 1980, and no fall drawdown of the Saskeram Marsh took place. This caused substantial numbers of fish to remain trapped and, during the winter of 1980/81, sizeable fish kills were observed at the Cumberland Marshes Dam, Birch Lake control structure, and Bracken Dam. Fish kills were again observed during the winter of 1981/82 at the Birch Lake control and Bracken Dam. The majority of the fish killed during the two winters were pike, with adults of the species discovered below the Cumberland Marshes Dam, and juveniles found in the Saskeram Marsh.

Controversy regarding the effects of major wetlands projects on fisheries followed the discovery of the 1981-1982 fish kills, which were widely reported in the media. The timing of the fish kills coincided with dry years and critical hay shortages in the area, and produced disagreement between agricultural and wildlife interests over land use practices in the Saskeram Marsh.

The 1981 and 1982 winter kills were the first documented in the Saskeram Marsh, although summer kills, resulting from increased temperature and resultant oxygen loss, have been reported on occasion (Derksen, pers. comm.).

A number of winter fish kills have occurred in the past at Cut Beaver Lake in the Cumberland Marshes. A winter fish kill occurred in 1963 following completion and closure of the Dragline control structure. As well, winter fish kills took place in successive years in the mid 1970s during improvements to the Dragline Channel. A number of small fish kills were observed in the early spring of 1980 adjacent to control structures and in deep water areas of many Marsh units (Phillips, 1983). These fish had entered the Marsh units from the Cut Beaver reservoir the previous year. From 1981 to 1985, annual winter fish kills of varying magnitude have been observed in the Birch River below the Cumberland Marshes Dam (Phillips, pers. comm.).

Following the 1982 winter fish kill, a dissolved oxygen survey of the Saskeram Marsh was undertaken in February 1982, at the request of the Prairie Provinces Water Board. Dissolved oxygen concentrations near 0.0 mg/L were found throughout the entire Saskeram Marsh (Dunn, 1982). A localized zone of higher oxygen levels was found to be present in the Birch River below the Cumberland Marshes Dam, due to open water caused by Dam leakage.

Low dissolved oxygen concentrations in the marshes and connecting channels of the Cumberland and Saskeram Marshes had been reported earlier by Royer (1966), Saskatchewan Fisheries (1979,1980), and by Manitoba Water Standards and Studies (1981). Fisheries personnel generally agree that the Dragline Channel and Cut Beaver Lake are the only water bodies within the Cumberland-Saskeram complex suitable for the overwintering of fish, although some fish do overwinter, with varying degrees of success, in the Birch River and in deep water areas near control structures in the Saskeram Marsh (Saskatchewan Fisheries, 1979, Derksen, pers. comm.).

In an attempt to quantify the importance of the fishery in the Saskeram Marsh and the effects of wetland water management on that fishery, Ducks Unlimited (Canada) and Manitoba Natural Resources began a two-year study in May 1983. Recommendations of the study report will aim at reducing the severity of fish kills in the area, and at improving net fisheries benefits from the Saskeram Marsh (Derksen, pers. comm.).

In the interval before an overall fisheries management plan is instituted, four steps have been taken to reduce winter fish kills. These include: (1) the restriction of fish movement downstream from Cut Beaver Lake through the placement, in 1981, of fish screens at all outlets from the Lake; (2) the maintenance of flow in the Dragline Channel throughout the winter periods to ensure adequate oxygen supplies for fish overwintering in Cut Beaver Lake; (3) the passage of fall flows, beginning in the fall of 1982, through the Birch River to enhance pre-winter migration of fish out of the Saskeram Marsh; and, (4) the sealing of stop-log leakage through the Cumberland Marshes Dam, in the fall of 1983, to minimize the attractiveness of the reach below the Dam to fish during the late fall and winter.

2.2.2 Hydrologic Considerations

The fish protection steps taken in the Cumberland-Saskeram area are water quantity solutions to a water quality problem, insufficient concentrations of dissolved oxygen in the winter. Winter oxygen depletion occurs naturally in most marsh systems, due to relatively shallow water depth and high under-ice oxygen use during microbial breakdown of plant materials. Successful management of coexistent fisheries and waterfowl resources requires that care be taken during water movements to reduce the possibility of fish entrapment. Since 1982, sizeable fish kills have been reported at only one location, the Birch River immediately below the Cumberland Marshes Dam. It is probable, therefore, that the measures implemented to aid the fishery have been largely effective.

Interprovincial eastward flowing streams are subject to agreements which guarantee that over-border flows remain at 50 percent of natural flow. The flow in the Birch River is currently

not apportioned and, hence, natural flows at the Saskatchewan-Manitoba border are not calculated. The relatively short-term hydrologic data base and the controlled nature of water movement through the Birch River makes calculation of natural flow difficult. A study is currently underway to develop procedures for this calculation. The results of this study may have implications with regard to the fisheries issue, and for water management in the Cumberland Marshes in general.

It is noteworthy that the construction of the Gardiner Dam on the South Saskatchewan River significantly reduced the frequency of spring overland flooding from the Saskatchewan River during the late 1960's (Allison, pers. comm.). This may, over the long term, increase the requirement for direct water importation, via the Dragline Channel, to the Cumberland Marshes.

2.2.3 Water Quality Considerations

Water quality monitoring was initiated in 1979 as a result of concern that the Cumberland Marshes Project might have an impact on the quality of waters crossing the interprovincial boundary and, thereby, affect downstream usage. These water uses, in addition to waterfowl and fisheries use in the Saskeram Marsh, include municipal domestic use of Saskatchewan River water by the town of The Pas.

Concern about the Project was based upon a number of factors. Very little was known about the existing quality of the Birch River system prior to 1979. At that time, the chemical data base was limited to oxygen data reported by Fisheries personnel. Little information on water quality in similar wetlands projects was available in the literature. It was felt that the flood/drawdown cycles designed to enhance emergent marsh growth would lead to increased decomposition, resulting in an increased rate of eutrophication and higher oxygen demand, and that the undesirable products of anoxia, such as ammonia, sulphides, and trace metals, might have effects on the downstream fishery and other uses.

3.0 STUDY METHODS

Water quality monitoring in the Cumberland Marshes was initiated in June, 1979, and continued until August, 1984. Common sampling sites and hydrometric stations were established on the Dragline Channel below the inlet control structure, and on the Birch River immediately below the Cumberland Marshes Dam.

The sampling schedules called for the collection of twelve samples from each site yearly, with the majority of samples to be collected during the open water period, April to October. Approximately three samples were collected each year during the

winter periods as access permitted. Over the five year duration of the water quality study, 61 samples were collected from the Dragline Channel, and 58 from the Birch River. Ducks Unlimited (Canada) personnel stationed near Cumberland House collected the samples after receiving training in standard methods of water collection from Water Quality Branch staff.

The analytical list consisted of 39 parameters (Table 1), chosen to provide an overall characterization of the waters for physical and chemical components. Analyses according to approved methods were carried out at Water Quality Branch Laboratories in Calgary, Saskatoon, Burlington, and Regina.

Table 1 Analytical List for Cumberland Marshes Water Quality Study

Physical Parameters:	pH (lab), pH (field), specific conductance (lab), specific conductance (field), turbidity, colour, water temperature, dissolved oxygen, non-filterable residue
Major Ions:	total dissolved solids, total alkalinity, phenolphthalein alkalinity, calcium, magnesium, total hardness, bicarbonate, sulphate, chloride, silica, fluoride, sodium, potassium
Nutrients:	phosphorous total, nitrogen total, nitrogen particulate, nitrogen dissolved, nitrate-nitrite, total ammonia, carbon dissolved organic, carbon particulate organic
Metals and Organics:	total phenolics, arsenic dissolved, lead total, copper total, iron extractable, manganese extractable
Biological:	chlorophyll 'a', total coliform, fecal coliform

4.0 RESULTS AND DISCUSSION

Time series and seasonal plots are presented at the end of this report. Detailed water quality results are included in the Appendices. For plotting and statistical purposes, analytical results of 'less than detection limit' have been replaced with values equal to half the respective detection limits. Statistical results discussed in the text refer to data collected over the study period, when not qualified by specific time periods.

4.1 Characterization of Inflowing and Outflowing Waters

4.1.1 Hydrology

Detailed water quantity data for 1984, together with the Cumberland Marshes Project operational report for that year, are presented in the Appendices. Also included are hydrographs for 1979 to 1983 (data from Water Survey of Canada). The following information is a brief resume of Cumberland Marshes hydrology during the period 1979 through 1984.

Heavy accumulations of snow during the winter of 1978/79 made it unnecessary to import water through the Dragline Channel during 1979. Small amounts of Dragline flow occurred in May to July and in December, due to leakage of the Dragline control structure. An imported volume of 4,250 dam^3 resulted. A total volume of 43,910 dam^3 passed over the Cumberland Marshes Dam during the period early July to mid-September, with the water used to reflood the Saskeram Marsh, which had been dewatered in 1978. Internal water transfers were carried out among a number of marsh cells. Leakage through the Cumberland Marshes Dam maintained a stretch of open water below the Dam throughout the winter. Water Survey of Canada later estimated the leakage flow to be approximately 0.015 m^3/s. Instrument failure coupled with infrequent visits produced an incomplete hydrologic record during the year at the Birch River location.

Surface runoff during 1980 was near normal. Major water importation through the Dragline Channel took place, with much of the water used to complete refill of Saskeram Lake. A total volume of 99,200 dam^3 were imported, mostly during the period early June to late October. Minimal flows were maintained in the Dragline Channel through most of the remainder of 1980. A volume of 74,300 dam^3 were transferred to Manitoba during the period April 30 to October 15. As in 1979, a number of internal transfers were undertaken during 1980. The Birch River Marsh was drawn down during the fall to accomodate winter improvements to dykes. Gaps in the hydrometric record occurred again during 1980, due to recorder clock stoppages.

Below normal surface runoff occurred during 1981. A volume of 76,200 dam^3 passed through the Dragline Channel, with much of the water used to refill the Birch River Marsh. The majority of water import took place during the period August to mid October. Flow in the Dragline Channel was maintained during the winter of 1981/82, with discharge normally exceeding 0.2 m^3/s. A total of 30,100 dam^3 was transferred to Manitoba during the period early May to late October. The hydrometric record for the Birch River site was complete during 1981. Fish screens were installed on outlets from Cut Beaver Lake in August to prevent migration of fish downstream.

Surface runoff was once again below normal in 1982. Dragline Channel discharge totalled 76,300 dam^3 during the year, with most waters imported between early May and late August. As in the winter of 1981/82, flow was maintained during the winter of 1982/83 to sustain dissolved oxygen concentrations in Cut Beaver Lake. A volume of 51,100 dam^3 passed over the Cumberland Marshes Dam during the operating period, May 7 to October 18. Requests for additional flow to increase fish migration in the Saskeram Marsh were met between September 3 and October 18. Numerous internal water movements and level adjustments were carried out during the year.

For the third consecutive year, surface runoff was below normal during 1983. The Dragline control structure froze in the open position during the period November 1982 to February 1983, resulting in an early topping of Cut Beaver Lake. Spring and summer refill was not required and no flow passed through the Dragline Channel from mid-June to mid-November. Flow was resumed in mid-November, and once again maintained during the winter of 1983/84. A total volume of 19,400 dam^3 was imported during 1983. A volume of 22,500 dam^3 was transferred to Manitoba during the year, most of the water originating from McGregor Lake, which was drawn down during the period June 28 to August 31. Additional volumes were transferred during late October and November at the request of Fisheries personnel. During October, leaks between stop-logs in the Cumberland Marshes Dam were sealed with oakum. It was hoped that absence of flow below the Dam might cause fish to migrate from the Birch River prior to winter freeze up. This measure was apparently not successful since fish kills were again observed in the winters of 1983/84 and 1984/85.

A continuous discharge of approximately 0.7 m^3/s was maintained in the Dragline Channel during the winter of 1983/84 to protect fish stocks in Cut Beaver Lake. It was later determined that adequate water to accomodate Project needs could not have been imported during spring runoff, since flows in the Old Channel fell to near zero at the end of June. The winter refill proved to be a critical element in providing adequate storage. A total volume of 20,900 dam^3 was imported during the year. The Cumberland Marshes Dam was operational between late April and mid October. During this period, Project releases to Manitoba totalled 39,200 dam^3, with exported waters originating from drawdowns of McGregor Lake and Junction Lake, and from the Cut Beaver Lake storage reservoir. A detailed

Project operational report for 1984, together with the hydrometric record, is presented in the Appendices.

4.1.2 Physical Water Quality Parameters

Dissolved oxygen concentrations at the Dragline Channel ranged from 6.7 mg/L to 15.3 mg/L, with a median of 9.8 mg/L. A statistical summary of results from the Dragline Channel is presented in Table 2. The seasonal plot shows a tendency toward higher dissolved oxygen concentrations during the colder months, indicating a well oxygenated flow and probable low under-ice oxygen demand. The maintenance of winter oxygenation in the Dragline Channel was no doubt aided by the decision in 1981 to sustain flows during the winter periods to assist overwintering fish in Cut Beaver Lake.

The median dissolved oxygen concentration in the Birch River immediately below the Cumberland Marshes Dam was 8.5 mg/L, with a range from 4.5 mg/L to 14.0 mg/L (Table 3). Concentrations tended to decline during the winter periods, to approximately 5 mg/L. These oxygen levels are adequate for the majority of sport fish, with pike reported to be successful in waters having concentrations as low as 0.3 mg/L (Manitoba Water Standards and Studies, 1981).

As noted earlier, oxygen surveys conducted in marsh lakes and connecting channels of the Cumberland and Saskeram Marshes during 1979, 1981, and 1982 showed complete oxygen depletion in most areas, and the relatively high oxygen concentrations found at the Birch River site were probably due to leakage through the Dam, which caused a reach of open water and local re-oxygenation. During the February 1982 survey, oxygen concentrations were 0.0 mg/L immediately above the Dam, 4.6 mg/L in the open water below the Dam, and 0.0 mg/L in the Birch River above Birch Lake, approximately 10 kilometers below the Dam, indicating that the oxygenated reach was confined (Dunn, 1982).

It has been reported that the fish kills observed below the Cumberland Marshes Dam on February 23, 1981 followed an extreme cold spell when the normally open reach below the Dam froze over completely, probably producing a short-term oxygen shortage (Friesen, pers. comm.). At the time of the February 23 observation, dissolved oxygen at the Birch River location was determined to be 6.4 mg/L. Follow-up sampling by Manitoba Fisheries on February 28 showed the entire length of the system from Cumberland Marshes Dam to Bracken Dam, including the normally oxygenated zone on the Birch River, to be unsuitable for overwintering of fish (Manitoba Water Standards and Studies, 1981).

Repairs to the Cumberland Marshes Dam to eliminate stop-log leakage were completed in October, 1983. Samples collected during the winter of 1983-84 had dissolved oxygen concentrations of 5.7

Table 2 Summary of Study Results 1979 - 1984
Dragline Channel below Control Structure

Parameter	Mean(1)	Median	Minimum	Maximum	Samples
diss oxygen	10.4	9.8	6.7	15.3	48
pH lab	8.1	8.2	7.6	8.6	60
pH field	8.0	8.1	7.0	8.7	41
cond. lab	418.	406.	312.	596.	59
cond. field	379.	370.	283.	690.	52
turbidity	3.4	3.0	0.6	8.5	60
colour	23.	20.	10.	50.	60
temperature	9.4	10.0	0.0	21.0	55
T.D.S.	233.	217.	177.	351.	58
N.F.R.	5.1	4.4	0.5	18.	60
P total	0.040	0.035	0.008	0.15	58
N total	0.48	0.47	0.09	1.1	58
N dissolved	0.38	0.36	0.10	1.0	58
N partic.	0.10	0.09	<0.01	0.36	58
N NO23	0.14	0.07	<0.01	0.44	55
N NH3	<0.1	<0.1	<0.1	0.3	43
C dissorg	4.7	5.0	3.0	7.0	57
C partorg	0.59	0.53	0.07	1.8	58
chlor a	0.006	0.002	<0.001	0.11	59
phenol	0.002	0.002	<0.001	0.007	54
coliform-t	20.	6.	<2.	210.	33
coliform-f	21.	2.	<2.	490.	40
alkalinity t	149.	139.	110.	280.	58
alkalinity p	0.06	0.0	0.0	2.5	60
calcium	44.8	43.6	35.5	58.7	60
magnesium	16.0	15.3	10.9	26.2	60
hardness t	177.	170.	117.	244.	60
bicarbonate	182.	168.	132.	341.	58
sulphate	50.6	48.0	36.0	72.1	60
chloride	8.8	7.8	3.2	29.4	60
silica	2.3	2.0	0.1	5.1	60
fluoride	0.14	0.14	0.07	0.26	59
sodium	18.5	17.5	10.0	32.5	60
potassium	2.5	2.6	1.8	3.7	60
arsenic diss	0.0007	0.0007	<0.0005	0.0025	59
iron ext	0.13	0.11	0.02	0.65	46
manganese ext	0.05	0.03	<0.01	0.28	46
copper total	0.003	0.002	<0.001	0.012	53
lead total	<0.004	<0.004	<0.001 (2)	0.005	54

(1) Results expressed in mg/L with the exception of pH (pH units), conductance (uS/cm), turbidity (NTU), colour (TCU), temperature (deg C), phenolics (ug/L), and coliforms (no./100 ml).
(2) Detection limit changed during the study period.

Table 3 Summary of Study Results 1979 - 1984
Birch River below Cumberland Marshes Dam

Parameter	Mean(1)	Median	Minimum	Maximum	Samples
diss oxygen	8.6	8.5	4.5	14.0	44
pH lab	7.8	7.8	7.0	8.7	57
pH field	7.7	7.8	6.7	8.7	41
cond. lab	611.	568.	400.	1158.	56
cond. field	531.	510.	352.	850.	49
turbidity	4.0	2.2	0.8	44.	57
colour	51.	50.	20.	240.	55
temperature	11.3	13.	0.	23.	53
T.D.S.	320.	295.	218.	611.	55
N.F.R.	6.0	3.0	0.5	57.	57
P total	0.063	0.039	0.009	0.35	56
N total	1.02	0.97	0.52	2.9	55
N dissolved	0.88	0.83	0.45	2.3	51
N partic.	0.15	0.12	0.03	0.55	55
N NO23	0.017	0.01	<0.01	0.2	55
N NH3	0.14	<0.1	<0.1	1.3	44
C dissorg	15.1	16.0	4.1	25.	54
C partorg	0.95	0.67	0.24	5.6	55
chlor a	0.004	0.003	<0.001	0.03	57
phenol	0.004	0.003	<0.001	0.009	52
coliform-t	108.	2.	<2.	2000.	33
coliform-f	5.	<2.	<2.	56.	37
alkalinity t	178.	160.	117.	345.	55
alkalinity p	0.4	0.0	0.0	17.4	56
calcium	49.4	45.9	30.5	95.3	57
magnesium	21.7	20.1	13.6	41.2	57
hardness t	213.	191.	140.	408.	57
bicarbonate	216.	195.	127.	421.	55
sulphate	18.8	11.0	4.8	91.	56
chloride	75.6	73.0	41.0	171.1	56
silica	4.3	3.2	0.8	12.0	57
fluoride	0.13	0.13	0.08	0.22	55
sodium	42.0	40.5	23.6	89.3	56
potassium	5.1	4.9	2.6	9.4	57
arsenic diss	0.0006	<0.0005	<0.0005	0.0023	55
iron ext	0.83	0.36	0.02	6.9	49
manganese ext	0.19	0.07	<0.01	1.1	49
copper total	0.002	<0.001	<0.001	0.013	54
lead total	<0.004	<0.004	<0.001(2)	0.008	54

(1) Results expressed in mg/L with the exception of pH (pH units), conductance (uS/cm), turbidity (NTU), colour (TCU), temperature (deg C), phenolics (ug/L), and coliforms (no./100 ml).
(2) Detection limit changed during the study period.

mg/L (January 30) and 4.8 mg/L (March 5), similar concentrations to those recorded during earlier winters. Open water was again observed below the Dam (Phillips, pers. comm.), suggesting that under-Dam seepage may exceed through-Dam leakage at the site.

Dragline Channel median pH (laboratory) was 8.2, with a range from 7.6 to 8.6. Somewhat lower pH levels were recorded at the Birch River, with a median of 7.8, and a broader range from 7.0 to 8.7. The two sites showed similar seasonal trends of winter pH lowering. The trend was especially obvious in the Birch River. Winter pH reductions are caused by lower rates of winter photosynthesis resulting in a decrease in plant uptake of carbon dioxide, which forms a weak acid in the dissolved state. The reducing conditions caused by under-ice anoxia can lead to pH lowering through a number of other mechanisms as well.

True water colour at the Birch River, with a median of 50 true colour units (TCUs), normally exceeded that found at the Dragline Channel, with a median of 20 TCUs. Water colour in the Birch River tended to be highest during winter. Colour in water is affected by a number of factors. Iron is a strong colour producing agent most prevalent during anaerobic conditions, which cause reduction to the mobile ferrous ion. The chemistry of manganese is similar to that of iron, and the free reduced manganous ion can also impart colour. The data for iron and manganese, discussed in Section 4.1.6, suggest that water colour at the Birch River site is at least partly due to the presence of these elements, which are present in elevated concentration, especially during the winter periods. The humic acids, weak organic acids not uncommon in waters draining bogs and marshes, are a common source of water colour as well. While humic acids were not analyzed during the study period, the results for dissolved organic carbon (see Section 4.1.4) suggest their probable presence.

Suspended matter concentrations were measured during the study period using the non-filterable residue (NFR) analytical technique. The two monitoring locations typically had low and similar NFR concentrations, with medians of 4.4 mg/L (Dragline Channel) and 3.0 mg/L (Birch River). NFR concentration at the two sites seldom exceeded 20 mg/L. An exception was a Birch River sample collected July 23, 1984 with an NFR concentration of 57 mg/L. The turbidity (laboratory) of this sample was very low, at 1.5 nephelometric turbidity units (NTU), indicating probable disturbance of the River bottom during sampling. The NFR result must, therefore, be considered an outlier.

NFR and turbidity results for the Dragline Channel tended to be lower during the winter periods, typical of most streams, and reflective of reduced discharge and water velocity. The Birch River site data indicated the opposite trend, with slightly higher suspended matter concentrations during the winter period. This may result from the release of particulate organic matter from the Cumberland Marshes following winter plant decay.

Specific conductance (laboratory), a physical indication of dissolved ionic concentration, and total dissolved solids (TDS), a calculation of ionic concentration derived from analytical results, were measured throughout the study period. The Dragline Channel median TDS was 217 mg/L, ranging from 177 mg/L to 351 mg/L. TDS varied inversely with the hydrograph, with winter concentrations approximately 40 percent higher than those measured in spring and summer.

Seasonal variability in TDS concentration was less predictable at the Birch River site. This was probably due to the complex hydrologic regime at this location, with water transferred at times directly from the Dragline Channel and Cut Beaver Lake, and at other times from marshes in drawdown. The residence time for waters passing over the Cumberland Marshes Dam is, therefore, extremely variable. The water quality variability expected to occur as a result of differing residence times would be dampened somewhat, however, by progressive dilution as waters move from west to east through the system. It is worth noting that the operational period of the Dam varied from year to year, from just over two months in 1979 and 1983, to as long as six months in 1981. As a result, a large number of Birch River samples, including open water samples, were collected during periods of minimal flow.

Total dissolved solids concentrations at the Birch River site were approximately 40 percent higher than at the Dragline Channel. The study period median TDS at Birch River was 295 mg/L, with a range from 218 mg/L to 611 mg/L. Higher TDS in the outflowing waters are to be expected due to in-marsh evaporation (partially balanced by local runoff and precipitation), to dissolution (which would be substantial due to slow transit time), and to possible local groundwater intrusion. The presence of saline bogs and lakes on lands to the south and east of the Cumberland Marshes suggests that even minor inputs of groundwater could add significant dissolved solids.

4.1.3 Major Ions

The relative abundance of major ions at the two monitoring locations during the study period were as follows (median concentrations in milliequivalents per liter are noted):

Cations

Dragline:	Ca (2.17) > Mg (1.26) > Na (0.76) > K (0.07)
Birch River:	Ca (2.29) > Na (1.76) > Mg (1.65) > K (0.13)

Anions

Dragline:	HCO3 (2.75) > SO4(1.00) > Cl (0.22) > Si (0.13) > F (0.01)
Birch River:	HCO3 (3.20) > Cl (2.06) > SO4(0.23) > Si (0.21) > F (0.01)

The waters of the Birch River contained substantially higher sodium and chloride concentrations than the Dragline Channel, and lower sulphate concentrations. The differences in concentration were sufficient to alter the orders of relative abundance for both cations and anions. Lower sulphate concentrations at the Birch River site may be due to the biological or chemical reduction of sulphate and subsequent release of hydrogen sulphide. Certain bacteria are able to utilize sulphate as an oxygen source for the breakdown of organic material, in the absence of dissolved oxygen and nitrate (Horne, 1978). Sulphate reduction would be most prevalent in winter, during periods of water column anoxia, but may occur in deep sediment throughout the year. The distinctive hydrogen sulphide odour was reported by Ducks Unlimited (Canada) personnel to be present during winter visits to the Birch River monitoring location (Phillips, pers. comm.). Analysis for sulphide in a sample collected on March 5, 1984 at the Birch River location showed a concentration of less than 0.05 mg/L sulphide. Winter sampling for sulphide had been initiated during 1982, but analytical difficulties produced unreliable results. A consistent decrease in Birch River winter sulphate concentrations from the winter of 1980-81 to the winter of 1983-84 is apparent in the time series plot. This may indicate a gradual change in the winter aerobic condition of the Marshes during that time period.

The seasonal plots for the Dragline Channel show summer-low winter-high annual trends for all parameters but potassium, which had the opposite trend, and chloride, which had no annual trend. The Birch River data show summer-low winter-high annual trends for all major ions with the exception of chloride which, as at the Dragline Channel, displayed no annual trend.

The differences in sodium and chloride concentrations between the two monitoring locations suggest that intrusion of saline groundwater may occur in the Cumberland Marshes. A number of major ions parameters in the Birch River reached their study period maxima on February 23, 1981, the date of discovery of the first major Cumberland Marshes Dam fish kills. While this might be coincidental, it may also indicate that inputs of mineralized (and anoxic) groundwater increased stress on overwintering fish.

4.1.4 Nutrients

Median total phosphorous concentration at the Dragline Channel was 0.035 mg/L, with a range from 0.008 mg/L to 0.15 mg/L. The median for the Birch River was only slightly higher, at 0.039 mg/L, but the range was broader, from 0.009 mg/L to 0.35 mg/L. Total phosphorous concentrations were similar at the two monitoring locations during the open water months, but they increased substantially at the Birch River site during the winter months. Following plant decay, phosphorous precipitated as inorganic phosphorous is thought to be bound in iron-inorganic phosphorous complexes of limited stability (Horne, 1978). It has been shown that, as anaerobic conditions develop, mobilization of the ferrous ion produces simultaneous increases in the iron and phosphorous flux into the water column (Hutchison, 1957). The similar variation in iron (extractable) concentration at the Birch River site (Section 4.1.6) suggests that iron mobilization is an important determinant to phosphorous release in this system. Despite the observed winter release of phosphorous, total phosphorous loading downstream would have remained low due to minimal winter discharge.

Total nitrogen concentrations at Dragline Channel ranged between 0.09 mg/L and 1.1 mg/L, with a median of 0.47 mg/L. Dissolved forms made up the majority of nitrogen present, with a median concentration of 0.36 mg/L. The median for particulate nitrogen was 0.09 mg/L. The time series and seasonal plots for total nitrogen showed no discernible annual trends. Highest concentrations of dissolved nitrogen typically occurred in late winter and early spring. During this time period, nitrates were the major dissolved form. Nitrate concentration decreased in late spring or early summer coincident with the major photosynthetic period, when plant nitrate demand is high and conversion to organic nitrogen forms occurs. The data for particulate nitrogen (largely made up of organic-N forms) agree with this, with increases in concentration seen to occur during the summer periods. Measureable total ammonia was present in three of forty-three samples collected. Samples collected in January and March, 1984 had total ammonia concentrations of 0.2 mg/L and 0.3 mg/L respectively.

The median total nitrogen concentration at the Birch River location was 0.97 mg/L, with a range from 0.52 mg/L to 2.9 mg/L. The median and maximum exceed those of the Dragline Channel by factors of two and three, respectively. As shown in the time series and seasonal plots, total nitrogen concentrations tended to be highest during the winter periods. Dissolved nitrogen forms accounted for the majority of total nitrogen. Particulate nitrogen, with a median of 0.12 mg/L, showed a trend toward maximum concentrations in winter, reflecting plant decay releases.

Nitrate concentrations were generally very low in the Birch River, with a median of 0.01 mg/L (at the analytical detection limit). An increase in nitrate concentration above those previously

observed occurred during one period, the fall and early winter of 1983-84, when concentrations reached 0.2 mg/L. This coincided with the period when maximum ammonia levels were reached. It is probable that nitrification occurred during this time period in the oxygenated reach below the Cumberland Marshes Dam. Very low nitrate concentrations at the Birch River site during the majority of the study period suggest, however, that nitrogenous oxygen demand was generally minor.

Through a process of elimination, it can be assumed that the predominant nitrogen form present in the waters of the Birch River is dissolved organic nitrogen, including proteins, their breakdown products such as polypeptides and individual amino acids, and other organic-N molecules. This is a result of the normal pattern of growth and breakdown which characterize marsh systems.

Over the study period, measureable total ammonia was present in eleven of fourty-four samples collected. Total ammonia concentration in the Birch River reached the study period maximum during the winter of 1983-84, peaking at 1.3 mg/L. Some evidence of denitrification was found during the winter of 1982-83, as well. While the ammonium ion has little or no toxicity to fish, ammonia in the un-ionized state is highly toxic to aquatic organisms, especially in situations of oxygen shortage. The United States Environmental Protection Agency (1985) has set criteria of 0.037 mg/L un-ionized ammonia as N (mean one hour concentration for acute toxicity), and 0.005 mg/L un-ionized ammonia as N (mean four day concentration for chronic toxicity). These criteria are for waters having pH of 7.5 and temperature of 0 C. The maximum un-ionized ammonia concentration found in the Birch River was 0.003 mg/L as N, below the established criteria. It is unlikely, therefore, that the presence of ammonia in the waters of the Birch River had either acute or chronic effects on the downstream fish during the study period.

The equilibrium reaction ($NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$) is pH dependent, with higher pH tending to move the equilibrium to the left. The concentration of un-ionized ammonia increases with temperature, and decreases with total ionic concentration. At typical Birch River winter pH (7.5 or less) and water temperature (0 C.), total ammonia would have to exceed approximately 14.3 mg/L to have acute effects on fish, and 2.1 mg/L to cause chronic effects.

Dissolved organic carbon at the Dragline Channel ranged between 3.0 mg/L and 7.0 mg/L, with a study median of 5.0 mg/L. Particulate organic carbon at the same site ranged from 0.07 mg/L to 1.8 mg/L, with a median of 0.53 mg/L. Both organic carbon parameters tended to decrease slightly during the winter months. The carbon data for Dragline Channel indicate a low rate of summer photosynthesis and winter oxygen demand.

Organic carbon concentrations were somewhat higher at the Birch River location. Dissolved organic carbon ranged from 4.1 mg/L to 25. mg/L, with a median of 16. mg/L. Particulate forms ranged between 0.24 mg/L and 5.6 mg/L, with a median of 0.67 mg/L. Both organic carbon forms showed a tendency toward higher concentrations during the winter. The dissolved carbon data from the Birch River support the probable presence of humic and fulvic acids, which are colour-causing organic acids not readily susceptible to breakdown. Other organic carbon compounds, including methane, are much more easily oxidized, and can add substantial biochemical oxygen demand.

To summarize, nutrients were generally present in higher concentration in the outflowing waters of the Cumberland Marshes than in the inflow. Total phosphorous in the Birch River reached concentrations near 0.3 mg/L during the winter periods, but export of phosphorous was thought to be minimal. Concentrations of most nitrogen and carbon species in the Birch River exceeded those found in the Dragline Channel throughout the year, indicating that net export of these nutrients does occur. This reflects the ability of autotrophs to capture atmospheric nitrogen and carbon sources, and would be expected to occur below any waterbody supporting substantial plant growth.

4.1.5 Biological Parameters

The median chlorophyll 'a' concentration at the Dragline Channel was 0.002 mg/L, ranging from <0.001 mg/L to 0.11 mg/L. Similar results were found at the Birch River location, with a median of 0.003 mg/L, and a range from <0.001 mg/L to 0.03 mg/L. No definite seasonal trends were visible at either site. These results are similar to those found in many prairie streams classed as oligotrophic or mesotrophic, and indicate low algal biomass in both the inflowing and outflowing water of the Cumberland Marshes. Ducks Unlimited (Canada) staff living on site have not observed periods of prolific periphytic or planktonic growth in the Marsh complex (Phillips, pers. comm.).

The data show no consistent indication that wildlife populations in the Cumberland Marshes caused increases in the bacterial populations in waters flowing from the Marshes. Coliform levels, both total and fecal, were typically low at both monitoring locations. Study period medians for total coliform were 6/100 ml and 2/100 ml at the Dragline Channel and Birch River sites, respectively. The corresponding fecal coliform medians were 2/100 ml and <2/100 ml. These bacterial counts are similar to those found in many prairie rivers removed from anthropogenic inputs.

On two occasions, total coliform counts at the Birch River location exceeded 1000 organisms per 100 ml. In both samples, however, the corresponding fecal coliform counts were at or near the detection limit of 2 organisms per 100 ml. The resultant ratio of

total coliform : fecal coliform is abnormally high, leading to the conclusion that the samples may have been affected by delayed time in transit. Bacteriological analyses were performed in the laboratory, and on a number of occasions problems with sample transport produced time delays of 72 hours between sampling and analyses, exceeding recommended storage times for bacteriological samples. Samples received in the laboratory more than 72 hours after sampling were discarded.

4.1.6 Metals and Phenolics

Dissolved arsenic concentrations at both locations were well below the criterion recommended for the protection of human health, 0.05 mg/L (USEPA, 1976). The median arsenic at the Dragline Channel was 0.0007 mg/L, with a range from <0.0005 mg/L to 0.0025 mg/L. The Birch River median arsenic was <0.0005 mg/L, with a range from <0.0005 mg/L to 0.0023 mg/L. Study period maxima at both sites occurred during 1983, coincident with a change in analytical method. Seasonal trends in arsenic concentration were not apparent at either site. Small amounts of arsenic occur in the environment naturally and the element reaches problematic concentrations in waters only through anthropogenic input.

Concentrations of both iron (extractable) and manganese (extractable) were found to be consistently higher at the Birch River location than at the Dragline Channel. Median concentrations at the Birch River location were 0.36 mg/L (iron) and 0.07 mg/L (manganese). Maximum concentrations were 6.9 mg/L (iron) and 1.1 mg/L (manganese), with both metals showing a very strong trend toward increased concentration in the winter periods. This seasonal trend probably results from the reduction of iron and manganese to the mobile ferrous and manganous ions under winter anaerobic conditions. As noted earlier, total phosphorous showed a similar strong seasonal trend at the Birch River site, and a number of writers have theorized on the relationship between phosphorous and iron in bottom sediments (Horne, 1978).

Median concentrations at the Dragline Channel were 0.11 mg/L (iron) and 0.03 mg/L (manganese). Maximum concentrations recorded at the site were 0.65 mg/L (iron) and 0.28 mg/L (manganese). At the Dragline Channel, iron showed a tendency to reach maximum concentration during the open water period, while manganese showed the reverse trend.

A criterion of 1.0 mg/L iron has been established for the protection of freshwater aquatic life (USEPA, 1976). This criterion was exceeded in eight of forty-nine samples collected at the Birch River location, with all exceedances occurring during the winter or early spring. It is probable, however, that the majority of the iron present in the waters of the Birch River are complexed with humic and fulvic acids. Complexed iron is rendered inactive

chemically and physiologically, and has little effect on aquatic life (ibid.).

Manganese concentrations in both the Dragline Channel and Birch River exceeded the criterion for domestic water use of 0.05 mg/L (USEPA, 1976) on a number of occasions. This criterion is based on staining and taste problems associated with manganese, not on health concerns. It is unlikely that winter manganese concentrations in the Birch River, where levels were typically in the range of 1.0 mg/L, would have serious effects on fish. Freshwater aquatic species have been reported to be tolerant to concentrations ranging from 1.5 mg/L to over 1000 mg/L (McKee and Wolf, 1963).

Results for total copper were similar at the two monitoring locations, with medians of 0.002 mg/L at the Dragline Channel and <0.001 mg/L at the Birch River site. Total copper seldom exceeded 0.01 mg/L at either site, and seasonal trends were not apparent. The toxicity of copper to aquatic life is dependent on a number of physical and chemical characteristics of water, including hardness. At a hardness of 200 mg/L (as CaCO3), typical of the Cumberland Marshes, a criterion concentration of .029 mg/L dissolved copper has been proposed (USEPA, 1983). This concentration was not approached during the study period.

Concentrations of total lead were at or near the detection limit of 0.004 mg/L throughout the study period at both sampling locations. A maximum concentration of 0.020 mg/L total lead for the protection of freshwater aquatic life (24 hour mean total lead at hardness of 200 mg/L), and 0.050 mg/L for the protection of human health, have been set by the U.S. Environmental Protection Agency (1980).

Similar concentrations of total phenolics were found at both sampling locations, with medians of 0.002 ug/L at the Dragline Channel and 0.003 ug/L at the Birch River. Maxima were 0.007 ug/L (Dragline Channel) and 0.009 ug/L (Birch River). Concentrations of phenolics above the background of earlier years occurred at both sites during mid-1983. Phenolic substances occur naturally in the environment, resulting from release by aquatic plants and vegetative decay (Water Quality Branch, 1979). McKee and Wolf (1963) reported that 200 ug/L phenol would not interfere with fish and other aquatic life, although other writers have reported changes in fish gills and tissues in the range from 20 to 70 ug/L (Reichenbach-Klinke, 1965). A criterion of 1 ug/L has been set in the U.S. for the protection of the freshwater environment (USEPA, 1976).

4.1.7 Summary

It is felt that the five year study carried out in the Cumberland Marshes has provided sufficient data to adequately characterize the chemical water quality of waters flowing into and

out of the Project area. The findings can be summarized as follows:

-dissolved oxygen concentrations at the Birch River site tended to remain at or near 5 mg/L during winter. This was surprising, considering that most internal marsh units of the Cumberland-Saskeram area are known to become totally anoxic during winter. It was concluded that re-oxygenation occurred in the sampling reach due to open water caused by seepage through the Cumberland Marshes Dam.

-the waters of the Birch River were relatively highly coloured, indicating the probable presence of humic and fulvic acids.

-both water colour and pH at the Birch River had strong seasonal trends, with colour maxima and pH minima during winter. Similar seasonal trends for iron and manganese led to the conclusion that colour in the Birch River was at least partially due to the presence of these metals.

-concentrations of total dissolved solids were approximately 40 percent higher in the Birch River than in the Dragline Channel.

-differing orders of abundance of anions and cations were found at the two sampling locations. Sodium and chloride concentrations were higher, and sulphate concentrations lower, in the outflowing waters.

-the simultaneous occurrence of maximum study period major ion concentrations and a major fish kill, in February, 1981, led to the conclusion that anoxic groundwater intrusion may have added to stress on fish during that time.

-seasonal variabilities in major ion concentrations at the Birch River location were irregular due to the complex hydrology.

-total phosphorous in the Birch River displayed strong seasonal trends, with concentration reaching near 0.3 mg/L each winter. The data for iron displayed the same trend, indicating that phosphorous is bound as ferric phosphate in bottom sediment during aerobic conditions. Export of phosphorous from the Marshes was thought to be minimal.

-nitrogen and carbon concentrations were generally higher in the outflowing waters than in the inflow and it was concluded that net export of nitrogen and carbon species occurred.

-measureable total ammonia was present in 11 of 44 samples collected from the Birch River. It was felt that the concentrations found were insufficient to have serious effects on overwintering fish. Evidence of nitrification of ammonia was found during the winter of 1983-84.

-the net export of algal biomass and coliform bacteria from the Cumberland Marshes was minor.

-iron concentrations in the Birch River exceeded criteria established for the protection of aquatic life during the winter periods, but it was felt that the majority of iron was bound to humic and fulvic acids, rendering it biologically unavailable.

-manganese, copper, lead, and total phenolics concentrations in the Birch River were below levels which might have detrimental effects on aquatic life.

Based on the findings, it is concluded that the water quality of the Birch River is typical of temperate marsh systems which produce winter anoxic conditions as a result of the substantial oxygen demand created by plant growth and decay cycles. The quality of waters leaving the Cumberland Marshes and crossing the Saskatchewan-Manitoba boundary is what would be expected in naturally occurring watersheds dominated by marshes.

4.2 Water Quality Trends

The confident identification of long term water quality trends usually requires very long term data sets, which allow the detection of changes in conditions over years beyond the 'noise' created by normal seasonal and hydrologic variation. The data set produced by this study does not extend over a sufficiently long period of time to allow in-depth analyses of water quality trends.

Trend analyses on these data are further complicated by the nature of the outflow from the Marshes, which is controlled in both water quantity and water source. The water quality at the Birch River site in a given year is largely dependent on the sources of waters being transferred to Manitoba. During 1980, the majority of the flow over the Cumberland Marshes Dam was derived from the drawdown of the Birch River Marsh. In 1983, the bulk of flow originated in McGregor Lake. During other years, waters were routed from other sources, including directly from Cut Beaver Lake through the Birch River and Birch River Marsh. Therefore, the marsh residence times and, presumably, the water quality of waters passing through the Cumberland Marshes Dam would be expected to be highly variable within and/or between years.

The data collected from 1979 to 1984 adequately characterize chemical water quality during that period. This baseline will be of use in the future for comparative purposes in the determination of long term trends, should future monitoring be deemed necessary.

4.3 Potential Effects of Outflowing Waters on Downstream Uses

4.3.1 Uses in the Birch River and Saskeram Marsh

Waters in the lower Birch River and Saskeram Marsh are currently used to support aquatic wildlife and fisheries. It has been well documented that anoxic conditions are present during winter in both the Cumberland and Saskeram Marshes. Anoxia leads to the production of compounds, including ammonia, sulphides, and reduced trace metals, that can have chronic or acute effects on aquatic species. With the possible exception of iron, no evidence was found during the study period that the concentrations of these substances in the outflowing waters of the Cumberland Marshes were sufficient to cause serious effects on downstream aquatic life. While winter iron concentrations in the Birch River exceeded the criterion level of 1.0 mg/L (USEPA, 1976) established for the protection of freshwater aquatic life, it was felt that the majority of iron present is bound to humic materials, rendering it harmless. It is noteworthy that winter iron concentrations in the Carrot River, which successfully supports overwintering fish in the lower reaches, often exceeded 2.0 mg/L, and reached as high as 11.0 mg/L, during the period 1974 to 1979 (PPWB, 1984).

The mitigative measures carried out to date to reduce the numbers and severity of fish kills in the area appear to have been largely effective. Significant winter fish kills have not been observed in the Saskeram Marsh, Cut Beaver Lake, or within the Cumberland Marshes complex, since the winter of 1981-82 (Derksen, Phillips, pers. comm.). These measures, which include the maintenance of winter flow in the Dragline Channel-Cut Beaver River, the restriction of fish movement downstream from Cut Beaver Lake, and the fall flushing of Saskeram Lake, are water quantity related. However, insofar as they protect the fish resource from inhospitable water quality conditions, it is highly recommended that they be continued.

Winter fish kills continue to occur in the reach below the Cumberland Marshes Dam. Fish kills of varying magnitudes have been observed in this area every winter since 1980-81. To date, efforts to cause fish to move downstream through reduction in winter flow have apparently not been successful, and consideration should be given to alternative protective strategies, such as the passage of increased winter flow to sustain oxygenation of the reach. A recommendation in this regard may be included in the study report currently being prepared by Manitoba Natural Resources and Ducks Unlimited (Canada) (Derksen, pers. comm.).

4.3.2 Uses below the Saskeram Marsh

The major water use below the Saskeram Marsh outlet is direct municipal domestic use of waters of the Saskatchewan River by the town of The Pas, Manitoba. The Carrot River, into which the waters of the Saskeram Marsh flow, is a major tributary of the Saskatchewan River. The Carrot-Saskatchewan confluence is approximately seven kilometers upstream of The Pas.

Table 4 presents a comparison of the water quality of the Birch and Carrot Rivers. Data for the Carrot River were derived from the results of monthly sampling carried out at the Carrot River near Turnberry, approximately 50 kilometers upstream of the confluence of the Saskeram River, during the period April 1974 to December 1983 (PPWB, 1984).

As shown in Table 4, waters of the Birch River are generally of superior quality to those of the Carrot River when both medians and maxima are compared. Possible exceptions include total and dissolved nitrogen and dissolved organic carbon, for which the Birch River medians are slightly higher than those of the Carrot River. The Birch and Carrot Rivers drain similar geographic areas and, therefore, display many common characteristics, such as evidence of winter anoxia, high water colour, a high ratio of chloride:sulphate concentrations, and pronounced seasonal fluctuation of pH, iron, and manganese.

Table 5 provides a comparison of discharges in the two Rivers during the period 1979 to 1983. Discharge in the Carrot River typically exceeded that of the Birch River by a factor of at least five during the peak discharge, and by a factor of greater than thirty during the winter low flow period. During the period 1979 to 1983, total annual discharge at the Carrot River near Turnberry exceeded that in the Birch River below Cumberland Marshes Dam by factors of from four (1980) to thirty (1979 and 1983).

Table 4 Comparison of Water Quality in the Birch and Carrot Rivers

Parameter	Birch River 1979 - 1984 Median	Birch River 1979 - 1984 Maximum	Carrot River(1) 1974 - 1983 Median	Carrot River(1) 1974 - 1983 Maximum	Superior Quality (3) Median	Superior Quality (3) Maximum
diss oxygen	8.5	14.0	7.8	14.8		
pH lab	7.8	8.7	7.7	8.3		
pH field	7.8	8.7	7.6	8.5		
cond. lab	568.	1158.	1013.	4770.	B	B
cond. field	510.	850.	1010.	4625.	B	B
turbidity	2.2	44.	9.8	624.	B	B
colour	50.	240.	53.	280.		
temperature	13.	23.	4.3	24.		
T.D.S.	295.	611.	na	na		
N.F.R.	3.0	57.	14.	720.	B	B
P total	0.039	0.35	0.045	0.48		B
N total	0.97	2.9	0.71	3.5	C	B
N dissolved	0.83	2.3	0.63	2.0	C	
N partic.	0.12	0.55	0.11	1.6		B
N NO23	0.01	0.2	0.03	1.4	B	B
N NH3	<0.1	1.3	<0.1	1.4		
C dissorg	16.0	25.	12.0	22.0	C	
C partorg	0.67	5.6	0.70	12.1		B
chlor a	0.003	0.03	<0.005 (2)	0.04		
phenol	0.003	0.009	0.003	0.043		B
coliform-t	2.	2000.	15.	1500.	B	
coliform-f	<2.	56.	4.	80.	B	B
alkalinity t	160.	345.	217.	458.	B	B
alkalinity p	0.0	17.4	0.0	9.4		C
calcium	45.9	95.3	70.7	182.	B	B
magnesium	20.1	41.2	25.9	71.0	B	B
hardness t	191.	408.	294.	651.	B	B
bicarbonate	195.	421.	na	na		
sulphate	11.0	91.	65.	202.	B	B
chloride	73.0	171.1	160.	1280.	B	B
silica	3.2	12.0	11.4	20.	B	B
fluoride	0.13	0.22	0.15	0.34		B
sodium	40.5	89.3	108.	800.	B	B
potassium	4.9	9.4	6.7	24.0	B	B
arsenic diss	<0.0005	0.0023	0.0006	0.0022	B	
iron ext	0.36	6.9	1.1 (2)	11.0	B	B
manganese ext	0.07	1.1	0.21 (2)	4.0	B	B
copper total	<0.001	0.013	0.002 (2)	0.027	B	B
lead total	<0.004	0.008	<0.004 (2)	0.007		

(1) Data from monthly samples collected at the Carrot River near Turnberry during the period April 1974 to December 1983 (PPWB, 1984).
(2) Parameter was not analyzed continuously throughout the period.
(3) For most water quality parameters, lower concentration indicates superior quality. The sites are not ranked for parameters where concentrations are near equality, or where 'less is best' does not apply. C = Carrot River, B = Birch River, na = not available

Table 5 Comparison of Discharge in the Birch and Carrot Rivers 1979 - 1983

	Birch River below Cumberland Dam		Carrot River near Turnberry	
Year	Total Discharge dam3 (1)	Maximum Discharge m3/sec (2)	Total Discharge dam3 (3)	Maximum Discharge m3/sec
1979	43,900	12.1	1,200,000	241.
1980	74,300	11.3	322,000	64.9
1981	30,100	10.8	244,000	38.9
1982	51,100	10.6	427,000	82.8
1983	22,500	6.5	662,000	89.6

(1) data from Water Survey of Canada (Environment Canada 1979,1980, 1981,1982,1983)
(2) maximum daily discharge
(3) data from Water Survey of Canada annual hydrometric publications

Based on the available water quality/quantity data, it can be concluded that the effects of outflow from the Cumberland Marshes on the chemical water quality of the Carrot River were negligible during the study period. As a consequence, downstream use of the Carrot and Saskatchewan Rivers, including domestic use at The Pas, was not inhibited or limited by that outflow.

It should be noted that Dunn (1982) reported the presence of highly saline waters in the Elm Creek area of the Saskeram Marsh. The effect of this source on the waters leaving the Saskeram Marsh remains unknown.

4.4 Future Monitoring Considerations

The water quality data collected during 1979 to 1984 adequately characterize baseline chemical conditions during that period, and it is felt that continued water quality monitoring in the Cumberland Marshes is not required at this time. A need for future monitoring may become apparent, however, if major fish kills are observed during forthcoming years, if new construction or other significant Project changes occur, or if new downstream water uses are contemplated.

The Water Quality Branch, in recommending that monitoring of water quality be suspended, does not wish to imply that this Project should be exempt from ongoing licensing regulation. The responsibility for such regulation rests with the Province of Saskatchewan. If Ducks Unlimited (Canada) wishes to include water quality monitoring as part of its overall water management strategy, the Water Quality Branch will, if requested, provide related

assistance and advice.

At the time that monitoring began, concerns over the Cumberland Marshes Project were related to water chemistry. Therefore, the scope of this report is largely restricted to describing chemical characteristics. However, it should not be inferred that biological changes or effects are of lesser importance. Biological considerations would have to be the subject of further studies, should water resource management agencies require such a knowledge base.

Should monitoring in the Cumberland Marshes be planned in the future, a number of additional points would be worthy of consideration:

-Future work should be restricted to specific periods of the year. These include mid- to late-summer, when the majority of interprovincial flow normally occurs, and winter, when the Marshes become anoxic.

-A series of short duration but intense studies during these periods could provide the information required for the determination of long-term trends, and would allow the investigation of media other than water (fish, plants, and bottom sediments). To be compatible with the 1979-84 baseline, the Birch River monitoring location should be maintained, together with the 1979-84 parameter list. Future water quality study of the Dragline Channel may not be necessary. Saskatchewan River data collected as part of other studies should be sufficient in future to estimate the quality of inflow to the Cumberland Marshes.

-The water chemistry/biology of intra-Marsh units, and the quality of groundwater sources in the Marshes, including Elm Creek in the Saskeram area, merit investigation.

-As the Cumberland Marshes increase in waterfowl productivity, consideration should be given to the study of non-coliform bacteria and viruses.

5.0 CONCLUSIONS

The following conclusions were based on the monitoring results:

1. The five year data base is inadequate for confident documentation of water quality trends within the study period due to variabilities related to seasonal and inter-year hydrologic factors. The 1979-84 data set does provide sufficient information to adequately characterize general chemical water quality, and as such provides a basis against which future quality could be compared to determine long term trends.

2. The water quality of the Birch River is typical of marsh systems, which produce winter anoxic conditions as a result of the substantial oxygen demand created by plant growth and decay cycles. The quality of waters leaving the Cumberland Marshes and crossing the Saskatchewan-Manitoba boundary is as expected in naturally occurring watersheds dominated by marshes.

3. Concentrations of chemical constituents potentially affecting fisheries were, with the exception of iron, acceptable for the protection of aquatic life, according to criteria proposed by the United States Environmental Protection Agency (1976, 1980, 1983, 1985). While winter concentrations of iron were above the recommended criterion concentration, most of the iron was probably bound to humic and fulvic acids and, therefore, biologically unavailable.

4. The Cumberland Marshes Project did not cause significant degradation in the chemical quality of the Carrot River during the study period.

5. As a consequence of (4), the chemical quality of the Cumberland Marshes outflow did not inhibit or limit downstream water uses of the Carrot and Saskatchewan Rivers during the study period .

6.0 RECOMMENDATIONS

The following recommendations are based on the monitoring results, and on related information received from Provincial agencies:

1. Mitigative measures already implemented by Ducks Unlimited (Canada) to enhance dissolved oxygen levels in Cut Beaver Lake and minimize winter entrapment of fish within and below the Cumberland Marshes Project should be continued.

2. Monitoring of the chemical characteristics of the inflow to and outflow from the Cumberland Marshes Project Area has been adequately addressed related to interprovincial concerns and can, therefore, be discontinued. A need for future monitoring may become apparent if major fish kills are observed during forthcoming years, if new construction or other significant Project changes occur, or if new water uses are proposed.

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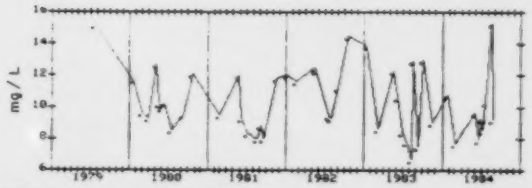
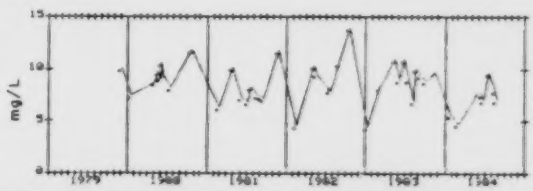
GRAPHS OF WATER QUALITY RESULTS

TIME SERIES PLOTS

DRAGLINE CHANNEL BIRCH RIVER

DISSOLVED OXYGEN





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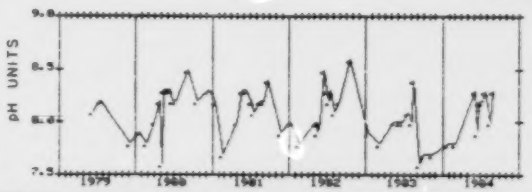

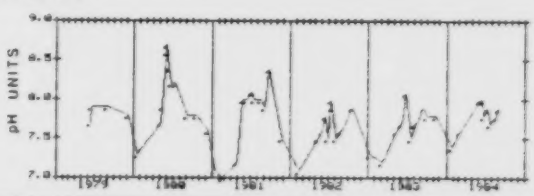

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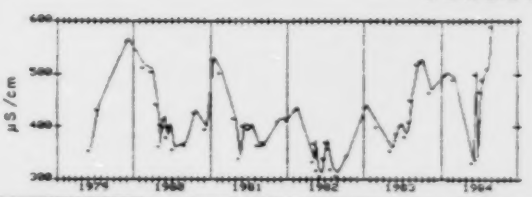

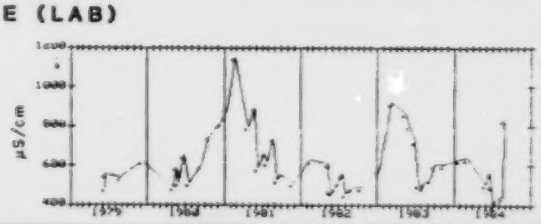

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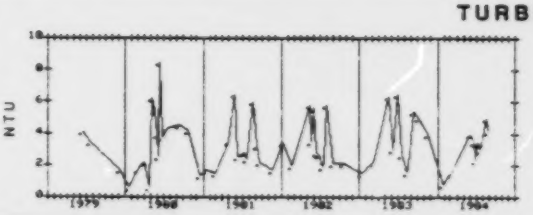

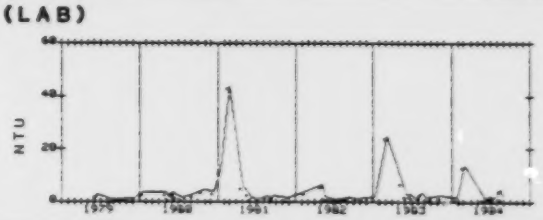

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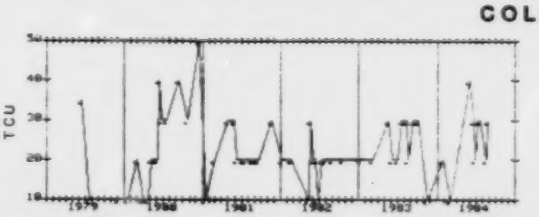

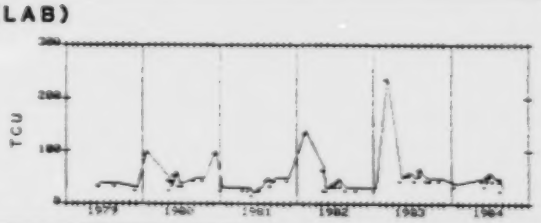

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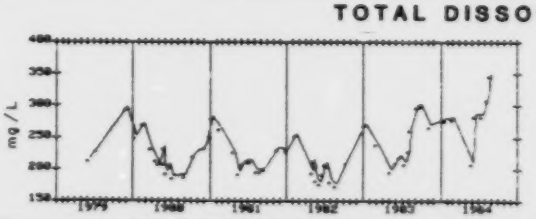
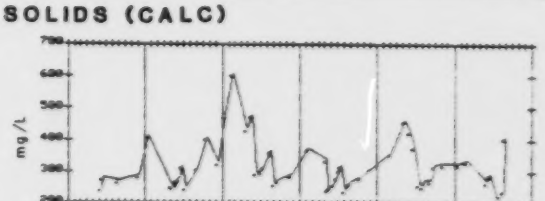
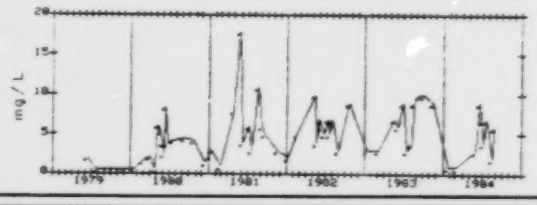


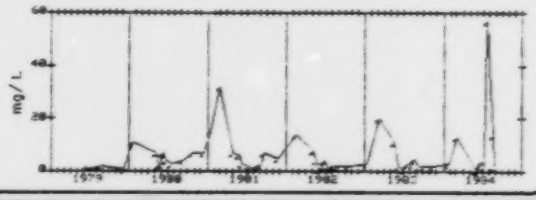


DRAGLINE CHANNEL

BIRCH RIVER

NON-FILTERABLE RESIDUE





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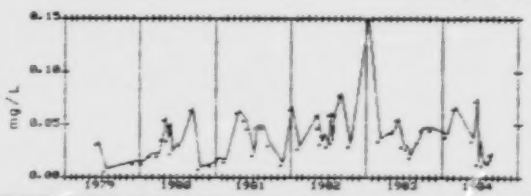

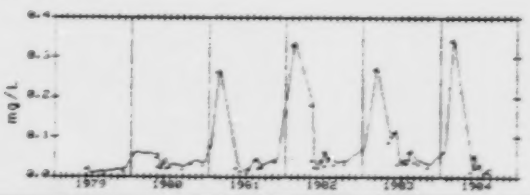

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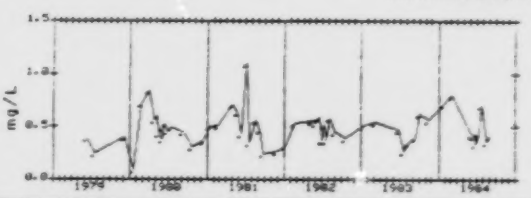

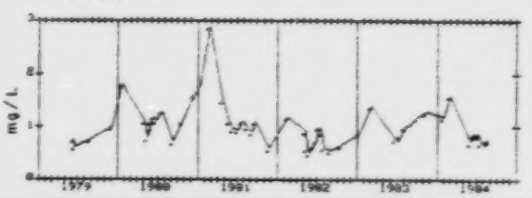

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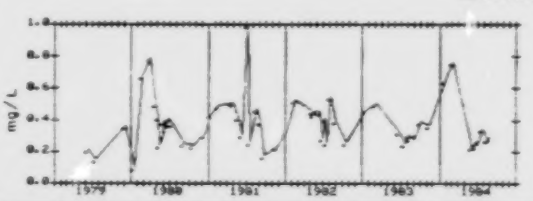

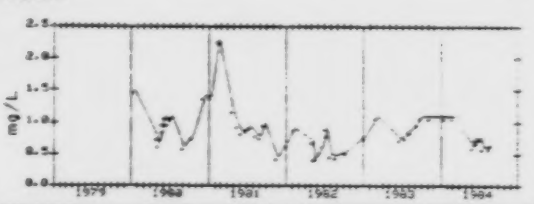

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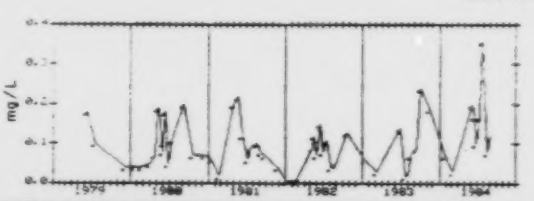

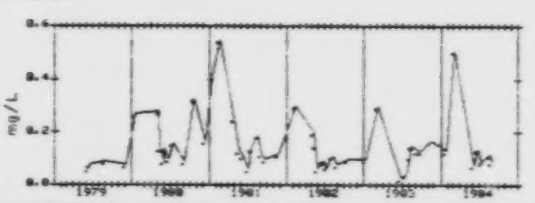

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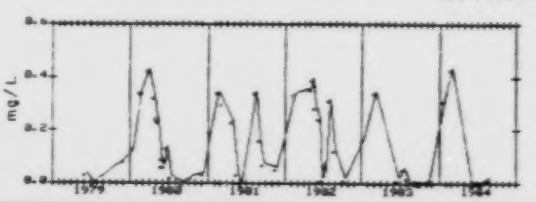
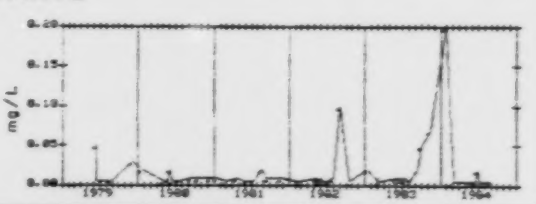
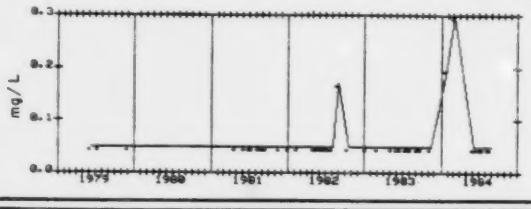


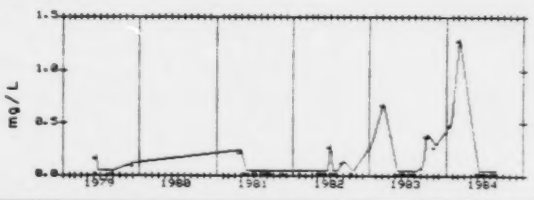


DRAGLINE CHANNEL

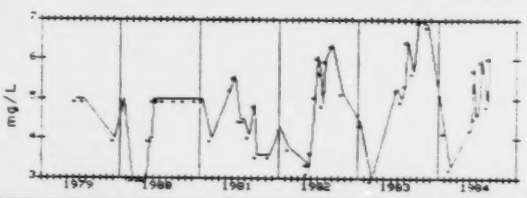
BIRCH RIVER

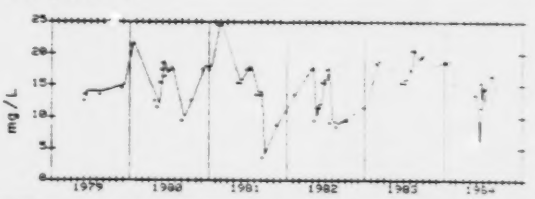
TOTAL AMMONIA



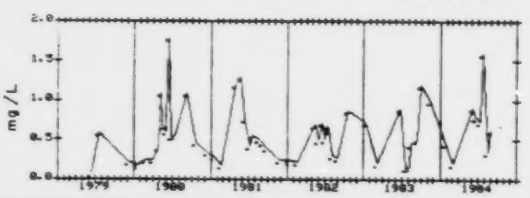


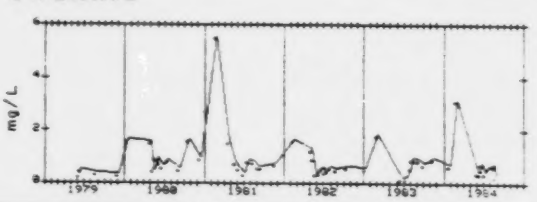
CARBON DISS. ORGANIC



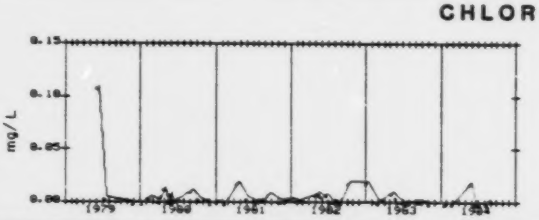


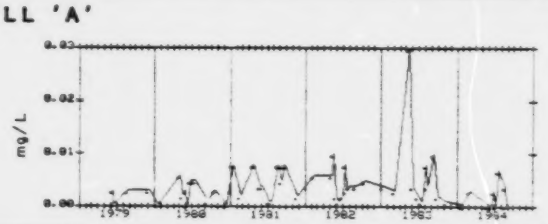
CARBON PART. ORGANIC



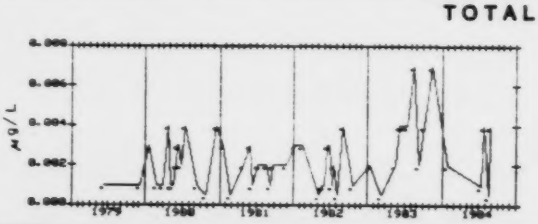


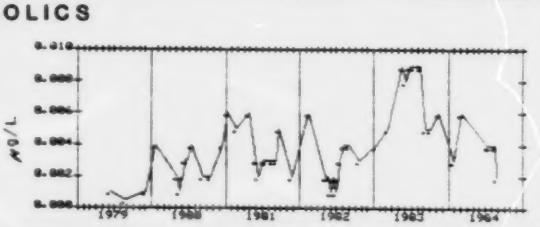
CHLOROPHYLL 'A'



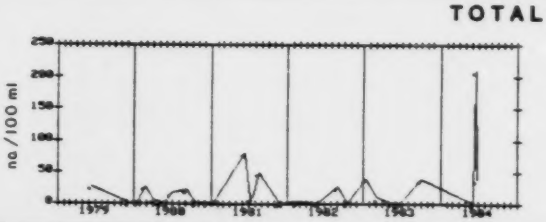


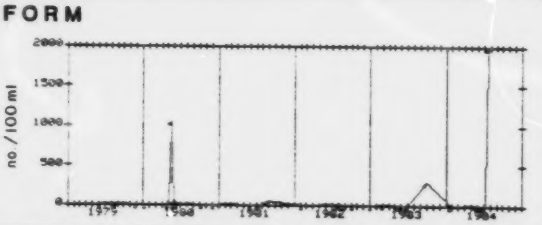
TOTAL PHENOLICS





TOTAL COLIFORM

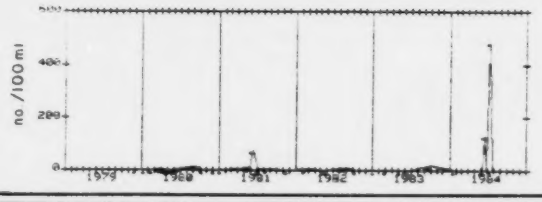


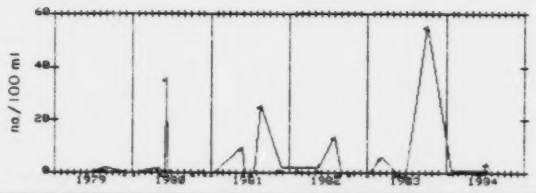


DRAGLINE CHANNEL

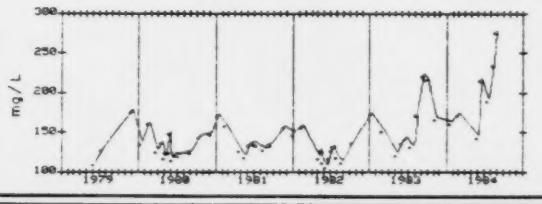
BIRCH RIVER

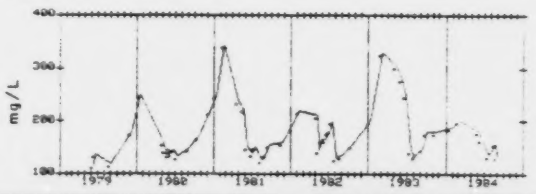
FECAL COLIFORM



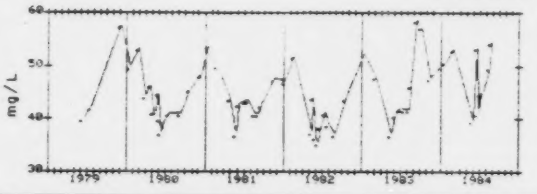


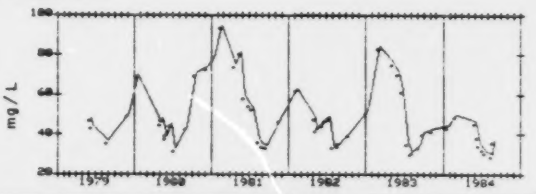
ALKALINITY TOTAL



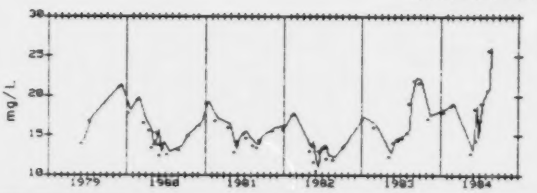


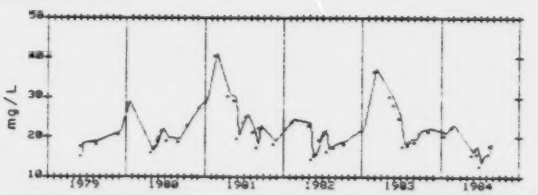
CALCIUM DISSOLVED



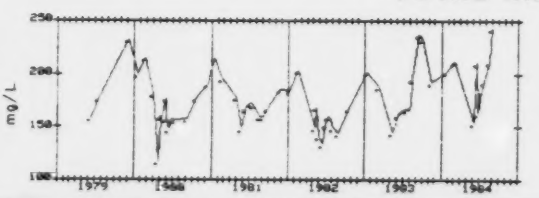


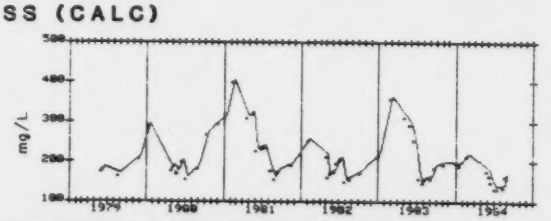
MAGNESIUM DISSOLVED



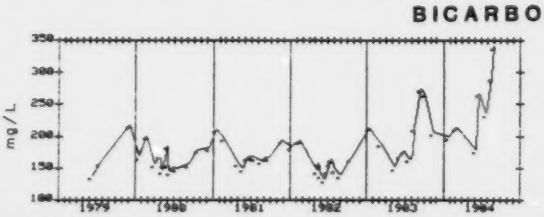


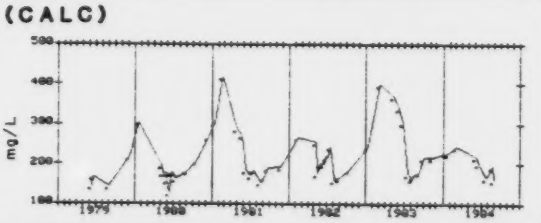
TOTAL HARDNESS (CALC)





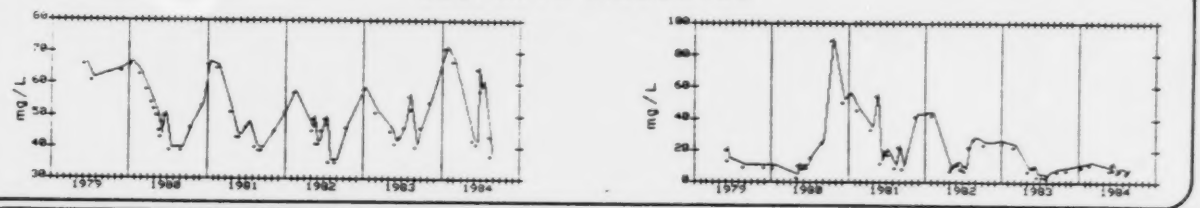
BICARBONATE (CALC)



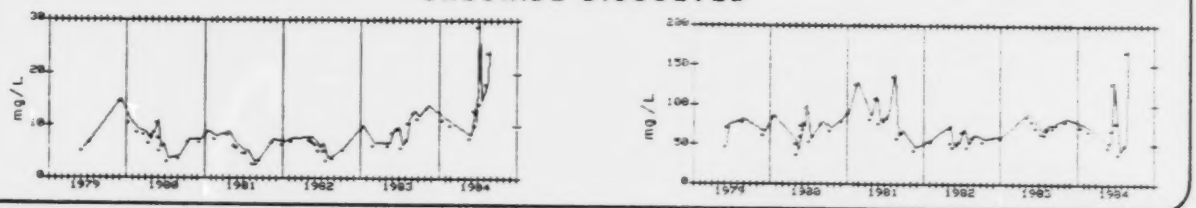


DRAGLINE CHANNEL BIRCH RIVER

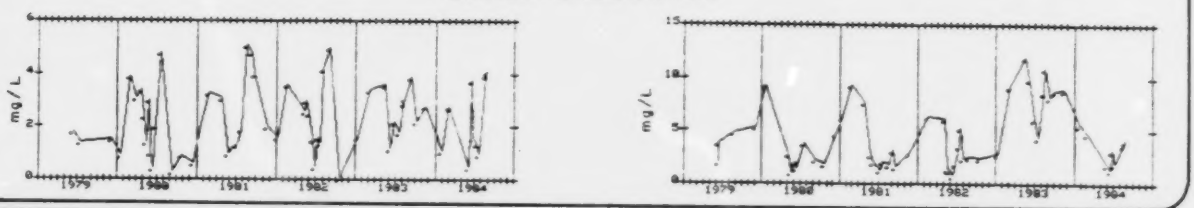
SULPHATE DISSOLVED



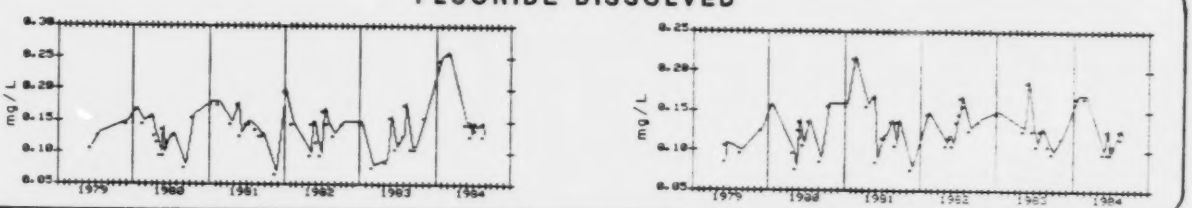
CHLORIDE DISSOLVED



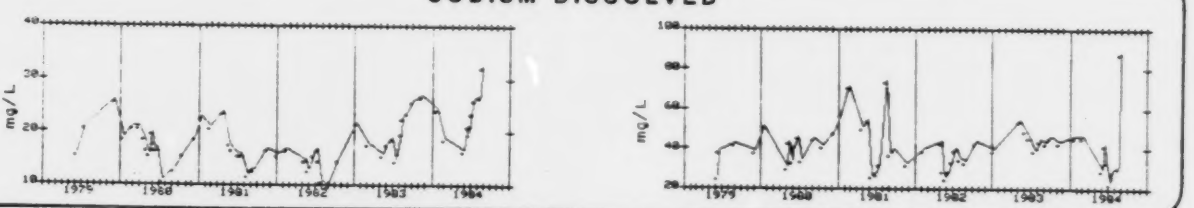
SILICA DISSOLVED



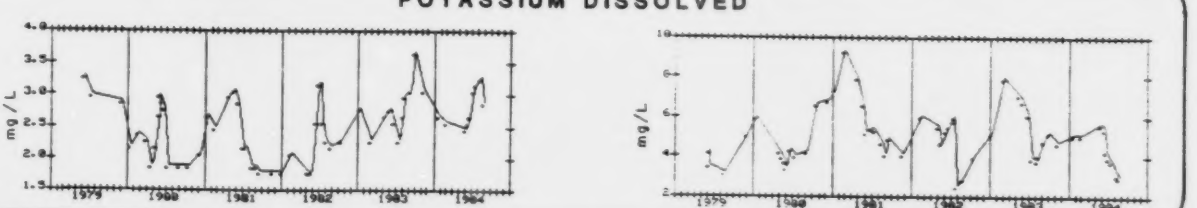
FLUORIDE DISSOLVED



SODIUM DISSOLVED

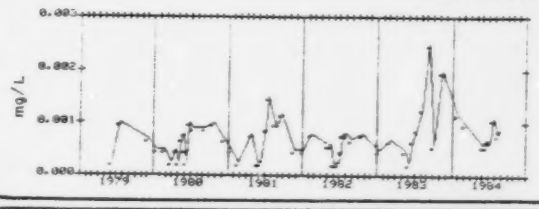


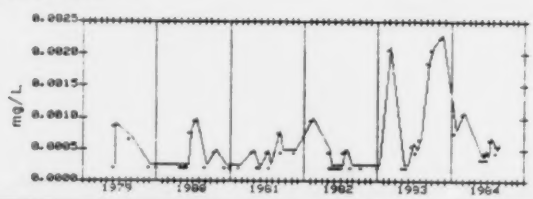
POTASSIUM DISSOLVED



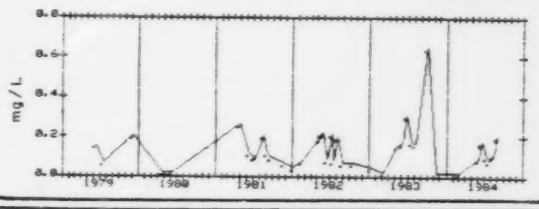
DRAGLINE CHANNEL BIRCH RIVER

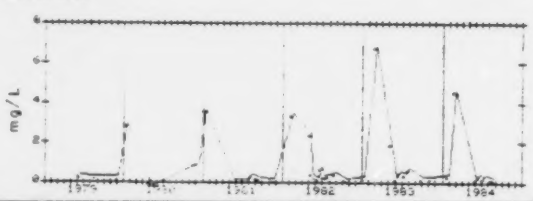
ARSENIC DISSOLVED



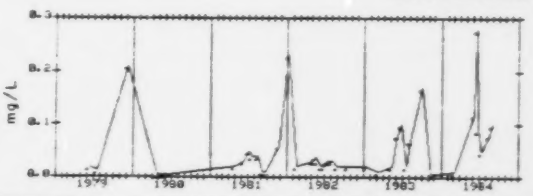


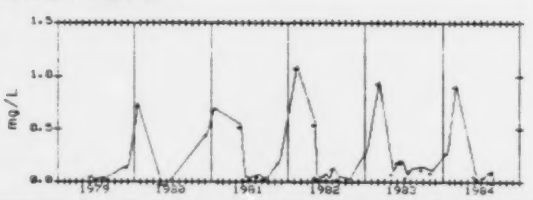
IRON EXTRACTABLE



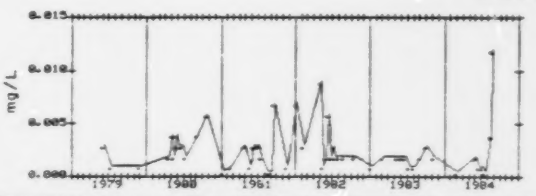


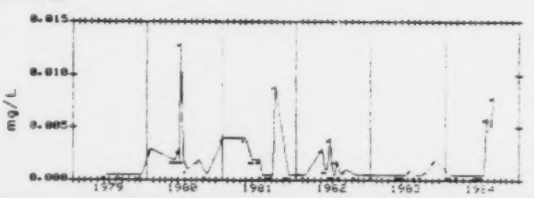
MANGANESE EXTRACTABLE



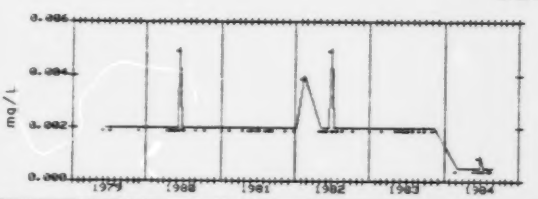


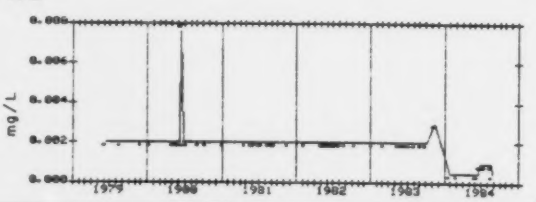
COPPER TOTAL





LEAD TOTAL



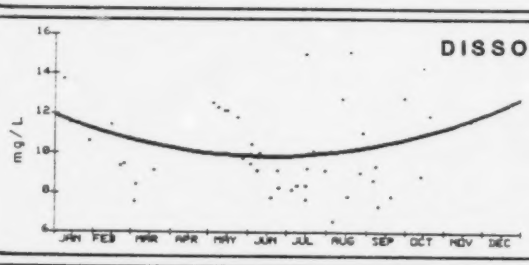


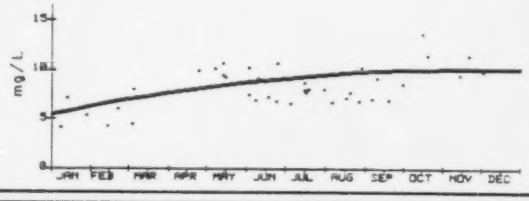
SEASONAL PLOTS WITH BEST SECOND ORDER FITS

DRAGLINE CHANNEL

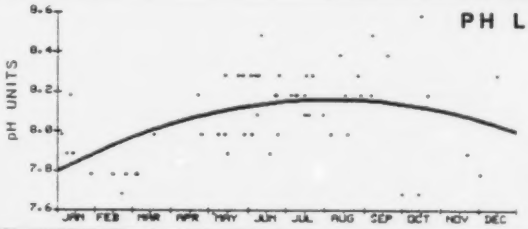
BIRCH RIVER

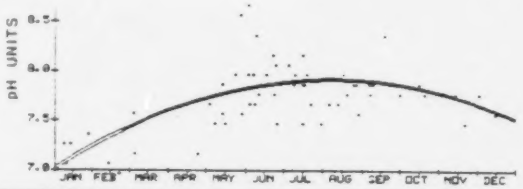
DISSOLVED OXYGEN



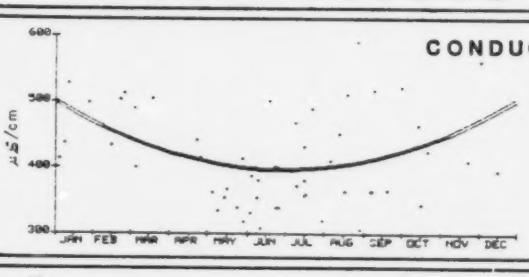


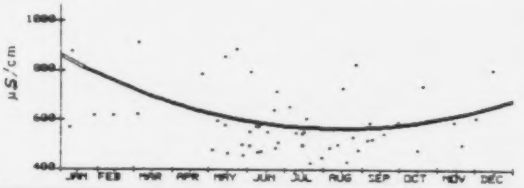
PH LABORATORY



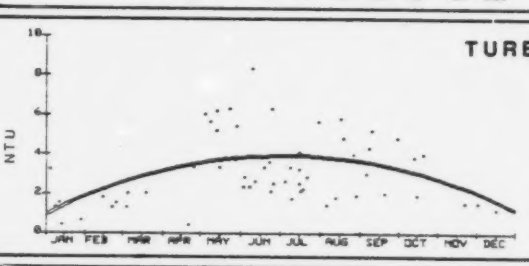


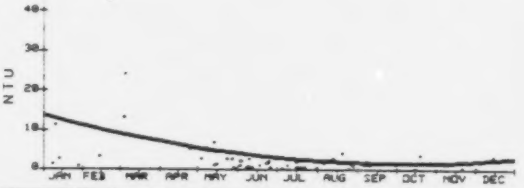
CONDUCTANCE (LAB)



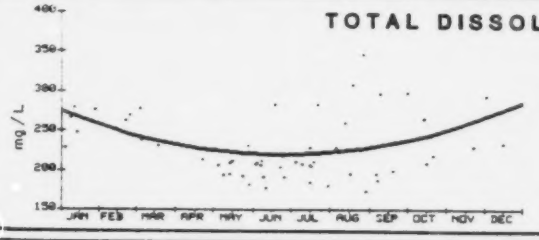


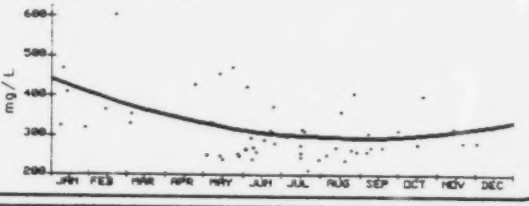
TURBIDITY (LAB)



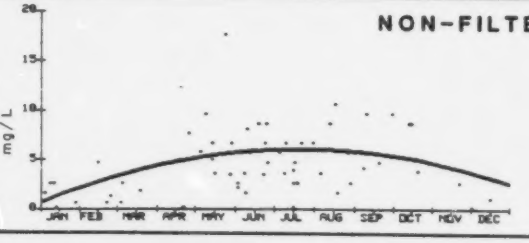


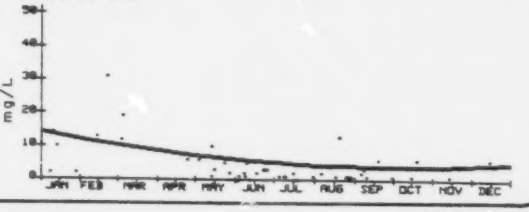
TOTAL DISSOLVED SOLIDS (CALC)





NON-FILTERABLE RESIDUE

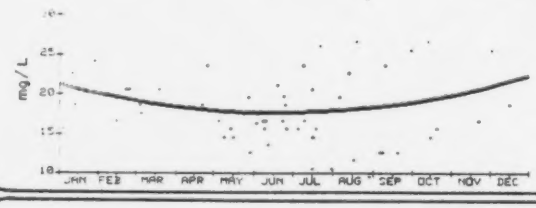


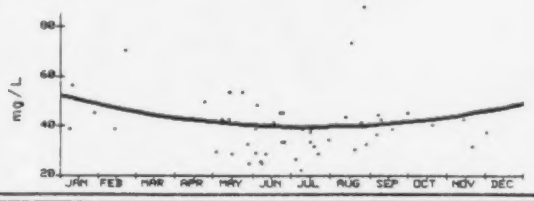


DRAGLINE CHANNEL

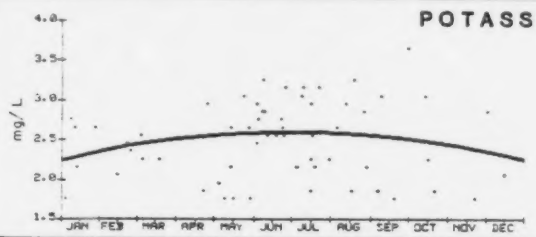
BIRCH RIVER

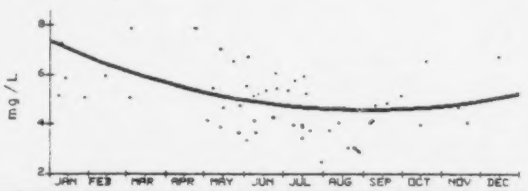
SODIUM DISSOLVED





POTASSIUM DISSOLVED





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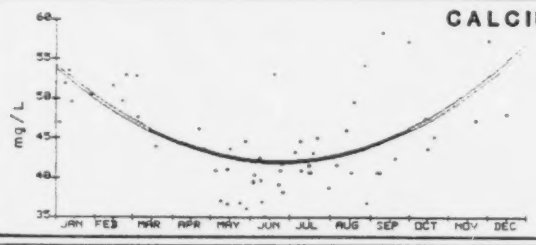

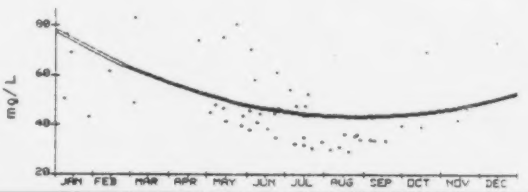

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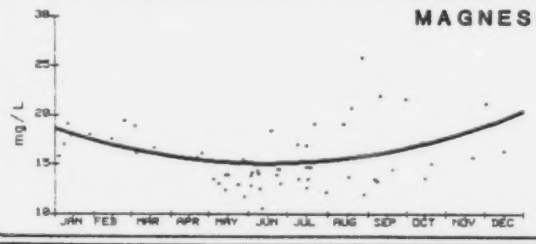

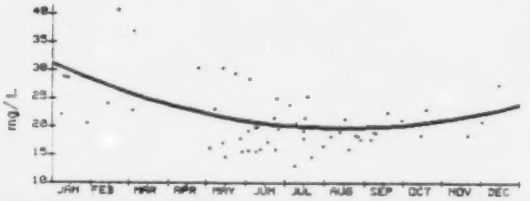

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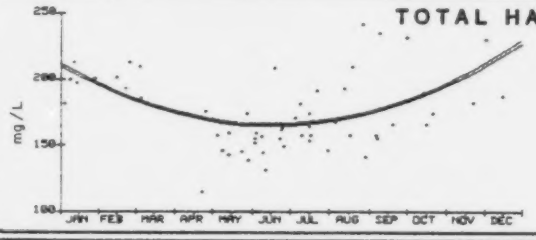

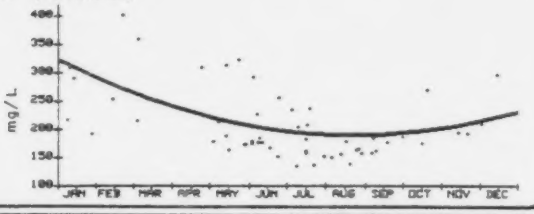

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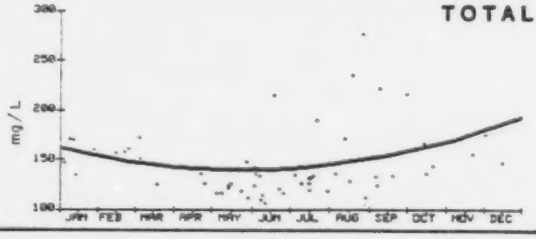
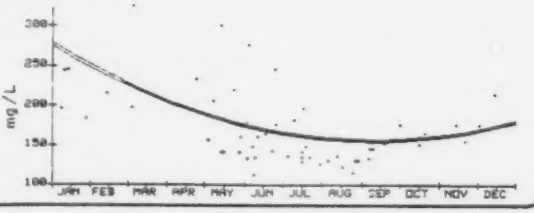
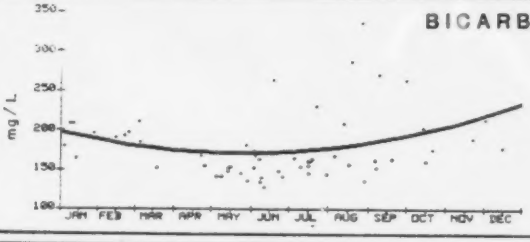


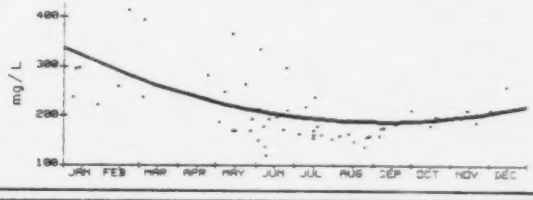


DRAGLINE CHANNEL

BIRCH RIVER

BICARBONATE (CALC)





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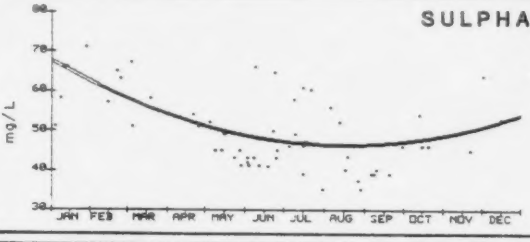

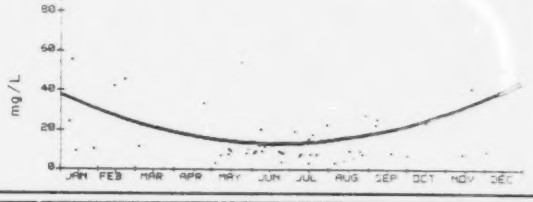

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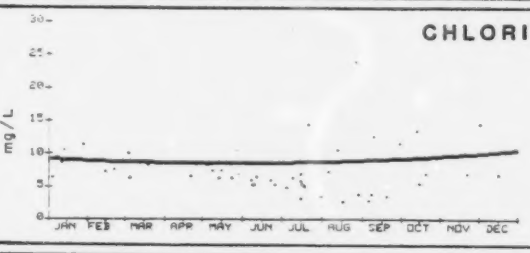

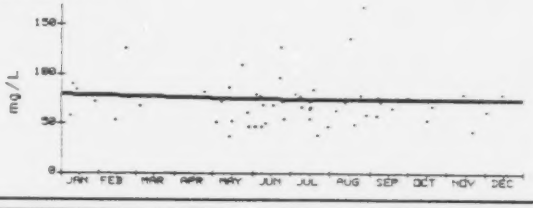

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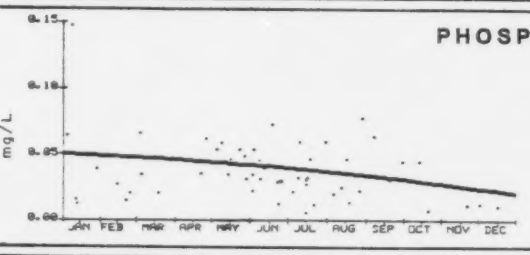

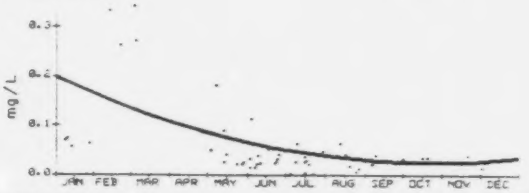

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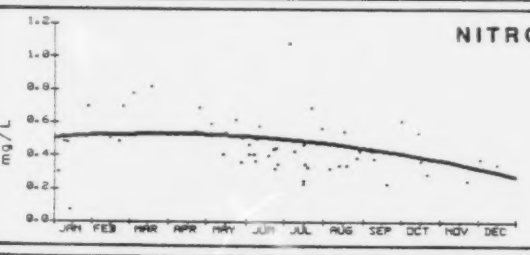

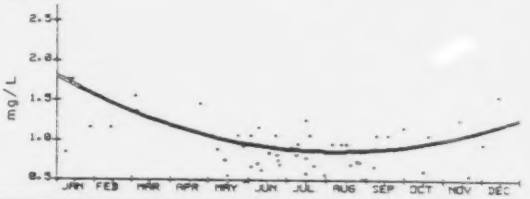

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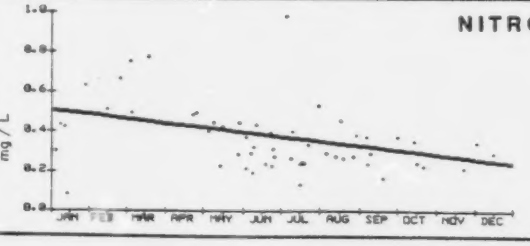
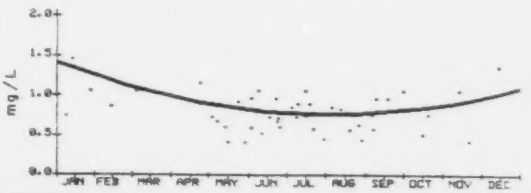
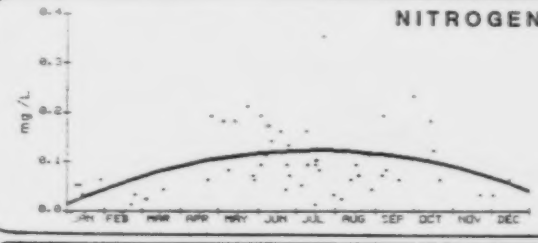


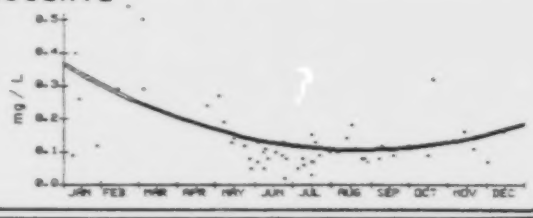


DRAGLINE CHANNEL

BIRCH RIVER

NITROGEN PARTICULATE





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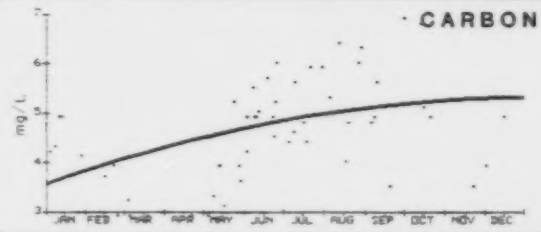

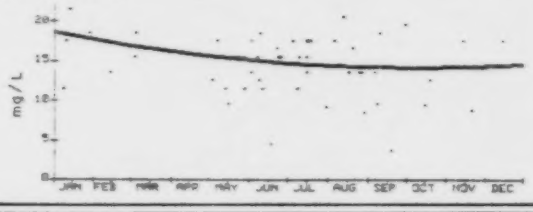

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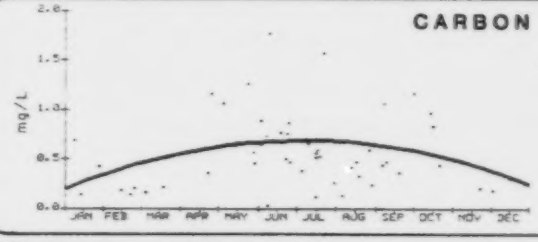

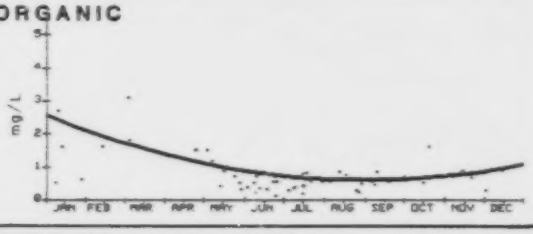

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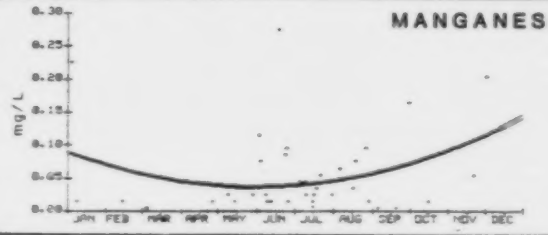

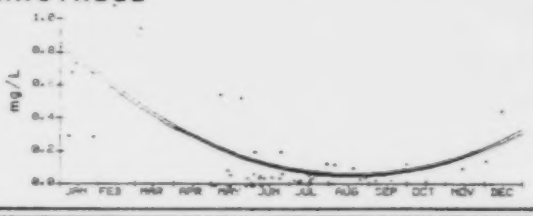

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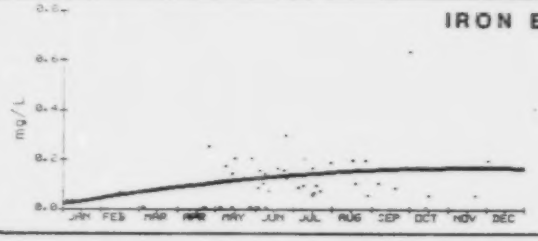

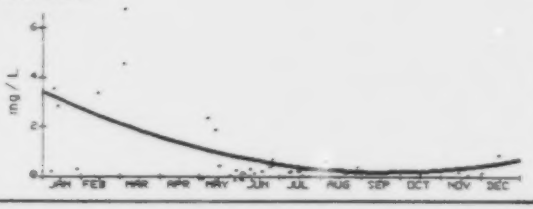

Environment Canada
Environmental Conservation Service

Environnement Canada
Service de la Conservation de l'environnement

Inland Waters Directorate
Western and Northern Region

Direction générale des eaux intérieures
Région de l'Ouest et du Nord

WATER QUALITY IN THE CUMBERLAND MARSHES

1979 - 1984

APPENDICES

JUNE, 1985

PREPARED FOR THE PRAIRIE PROVINCES WATER BOARD BY:

R. W. CROSLEY

ENVIRONMENT CANADA

INLAND WATERS DIRECTORATE

WATER QUALITY BRANCH

WESTERN AND NORTHERN REGION

REGINA, SASKATCHEWAN

WQB - W&NR - 85 - 03

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INTRODUCTION

This volume contains the Appendices to the report 'Water Quality in the Cumberland Marshes 1979-1984'. Detailed water quality data in tabular form are contained in Appendix A. A report on water quantity monitoring activities during 1984 is presented in Appendix B, together with the 1984 Cumberland Marshes operational report. Hydrographs from the Dragline Channel and Birch River monitoring locations for the period 1979 through 1983 appear in Appendix C.

The information contained in Appendices B and C were provided by Water Survey of Canada and by Ducks Unlimited (Canada).

APPENDIX A DETAILED WATER QUALITY RESULTS

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Julian Sum	Julian Date	Oxygen Diss	pH Lab	pH Field	Spec Cond (L)
11-JUN-79	162	162		8.1	7.6	360
18-JUL-79	199	199	15.2	8.2		437
04-DEC-79	338	338		7.8	7.4	567
15-JAN-80	380	15	11.7	7.9	8.2	
26-FEB-80	422	57	9.6	7.8	8.0	518
20-MAR-80	455	80	9.3	8.0	8.1	510
23-APR-80	479	114		8.2	8.2	447
06-MAY-80	492	127	12.7	7.6	7.9	368
15-MAY-80	501	136	10.2	8.3		408
29-MAY-80	515	150	9.9	8.3	3.0	419
04-JUN-80	521	156	10.1	8.3	8.3	405
11-JUN-80	528	163	10.2	8.3	8.1	385
24-JUN-80	541	176		8.2		407
17-JUL-80	564	199	8.5	8.2	8.5	362
09-SEP-80	618	253	9.5	8.5	8.7	370
22-OCT-80	661	296	12.1	8.2	8.4	431
17-DEC-80	717	352		8.3		400
13-JAN-81	744	13		8.2	7.6	533
23-FEB-81	785	54	9.5	7.7	7.6	508
28-APR-81	849	118		8.0	7.9	421
26-MAY-81	877	146	12.0	8.3	8.5	345
10-JUN-81	892	161	9.3	8.3	8.2	406
07-JUL-81	919	188	8.3	8.2	7.8	401
21-JUL-81	933	202		8.1	7.2	404
19-AUG-81	962	231	8.0	8.2	8.0	369
08-SEP-81	982	251	8.8	8.2	8.2	370
22-SEP-81	996	265	8.0	8.4	8.4	371
24-NOV-81	1057	328	11.8	7.9	8.2	415
06-JAN-82	1102	6	12.0	8.0	8.1	418
16-FEB-82	1143	47	11.6	7.8	7.7	438

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Julian Sum	Julian Date	Oxygen Diss	pH Lab	pH Field	Spec Cond (L)
11-MAY-82	1227	131	12.5	8.0		339
18-MAY-82	1234	138	12.3	7.9		373
31-MAY-82	1247	151		8.0		323
14-JUN-82	1261	165		8.5		313
28-JUN-82	1275	179		8.3	8.2	345
12-JUL-82	1289	193		8.2	7.8	377
19-JUL-82	1296	200	9.4	8.3	7.6	364
02-AUG-82	1310	214	9.3	8.1	7.6	325
31-AUG-82	1339	243	11.2	8.2		312
18-OCT-82	1387	291	14.5	8.6		349
10-JAN-83	1471	10	13.9	7.9		441
07-MAR-83	1527	66	8.6	7.8		405
16-MAY-83	1597	136	12.3	8.0	8.2	359
06-JUN-83	1618	157	10.6	8.0	8.4	392
27-JUN-83	1639	178	8.4	8.0		406
18-JUL-83	1660	199	7.8	8.1	8.2	386
08-AUG-83	1681	220	6.7	8.0		415
15-AUG-83	1688	227	12.9	8.4	7.6	457
12-SEP-83	1716	255	7.5	7.6	7.4	523
03-OCT-83	1737	276	13.0	7.7		528
16-OCT-83	1781	289	9.0	7.7		470
12-DEC-83	1807	346				
30-JAN-84	1856	30	10.8	7.8		503
05-MAR-84	1891	65	7.7	7.8	7.2	495
04-JUN-84	1982	156	9.6	8.3	7.0	337
20-JUN-84	1998	172	7.9	7.9		506
25-JUN-84	2003	177	9.3	8.2		344
10-JUL-84	2018	192	8.5	8.2	8.2	473
23-JUL-84	2031	205	10.3	8.3	8.4	495
20-AUG-84	2059	233	15.3	8.0	8.3	516
28-AUG-84	2067	241	9.2	8.3	8.3	596

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Spec Cond (F)	Turb Lab	Colour Apparent	Temp Field	T.D.S. Calc	N.F.R. 105 C
11-JUN-79	480	4.1	35		216	2.0
18-JUL-79	410	3.4	10		232	0.5
04-DEC-79	440	1.7	10	0.0	298	0.5
15-JAN-80	400	0.6	10	0.0	252	0.6
26-FEB-80	690	1.7	20	1.0	274	1.7
20-MAR-80	400	2.2	10	0.0	235	2.2
23-APR-80	360	0.6	10	1.0	217	0.6
06-MAY-80	420	6.2	20	5.0	211	6.2
15-MAY-80	325	5.4	20	14.0	213	5.4
29-MAY-80	360	3.9	20	13.0	235	3.9
04-JUN-80	350	2.5	20	15.0	212	2.5
11-JUN-80	300	8.5	40	16.0	196	8.5
24-JUN-80	300	3.8	30	20.0	208	3.8
17-JUL-80	310	4.3	30	14.0	189	4.3
09-SEP-80	310	4.5	40	13.5	191	4.5
22-OCT-80		4.2	30	4.0	223	4.2
17-DEC-80		1.4	50	1.0	238	1.4
13-JAN-81		1.7	10	1.0	283	3.0
23-FEB-81		1.5	20	1.5	267	1.0
28-APR-81	375	3.5	30	1.0	231	8.0
26-MAY-81	300	6.5	30	3.0	197	18.0
10-JUN-81	320	2.5	20	5.0	211	4.0
07-JUL-81	380	2.8	20	14.0	215	6.0
21-JUL-81	340	2.4	20	20.0	215	3.0
19-AUG-81	350	6.0	20	21.0	199	11.0
08-SEP-81	360	3.2	20	14.0	200	6.0
22-SEP-81	340	2.2	20	14.0	203	5.0
24-NOV-81	380	1.7	30	1.5	234	3.0
06-JAN-82	390	3.4	20	1.0	232	2.0
16-FEB-82	400	2.0	20	1.0	256	5.0

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Spec Cond (F)	Turb Lab	Colour Apparent	Temp Field	T.D.S. Calc	N.F.R. 105 C
11-MAY-82	325	5.8	10	2.0	198	10.0
18-MAY-82	350	3.5	30	5.0	216	4.0
31-MAY-82	315	5.6	20	10.0	186	7.0
14-JUN-82	330	2.8	20	20.0	181	6.0
28-JUN-82	360	2.7	10		196	5.0
12-JUL-82	390	1.9	20		212	7.0
19-JUL-82	370	2.3	20		209	5.0
02-AUG-82	325	5.8	20	15.0	184	7.0
31-AUG-82	320	2.1	20	10.0	177	3.0
18-OCT-82		2.1	20	3.0	213	9.0
10-JAN-83		1.5	20	1.0	271	3.0
07-MAR-83		2.2	20	0.5	242	3.0
16-MAY-83	283	6.4	30	1.0	200	7.0
06-JUN-83	370	3.0	20	12.0	213	6.0
27-JUN-83	369	6.5	20	17.0	222	9.0
18-JUL-83	375	2.7	30	19.0	211	3.0
08-AUG-83	419	1.6	30	21.0	233	4.0
15-AUG-83	480	2.0	20	15.0	264	9.0
12-SEP-83	429	5.4	30	19.0	301	10.0
03-OCT-83	405	3.0	30	7.0	303	10.0
16-OCT-83		4.0	10	4.5	270	9.0
12-DEC-83						
30-JAN-84	360	0.8	20	0.5	280	1.0
05-MAR-84	290	1.5	10	0.0	282	1.0
04-JUN-84	350	4.0	40	5.0	212	3.0
20-JUN-84	441	3.5	30	20.0	287	9.0
25-JUN-84	391	2.3	20	20.0		7.0
10-JUL-84	412	3.5	30	20.0		4.0
23-JUL-84	462	3.0	30	20.0	287	7.0
20-AUG-84	478	5.0	20	15.0	312	2.0
28-AUG-84	530	4.2	30	20.0	351	6.0

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	P Total	N Total	N Diss	N Part	N NO23	N NH3
11-JUN-79	0.034	0.39	0.21	0.180	0.040	0.05
18-JUL-79	0.008	0.25	0.15	0.100	0.005	0.05
04-DEC-79	0.015	0.40	0.36	0.040	0.090	0.05
15-JAN-80	0.015	0.09	0.10	0.040	0.130	
26-FEB-80	0.023	0.72	0.68	0.040	0.350	
20-MAR-80	0.023	0.84	0.79	0.050	0.430	
23-APR-80	0.038	0.57	0.50	0.070	0.330	
06-MAY-80	0.056	0.61	0.42	0.190	0.250	
15-MAY-80	0.037	0.43	0.24	0.190	0.240	
29-MAY-80	0.051	0.38	0.30	0.080	0.070	
04-JUN-80	0.025	0.49	0.39	0.100	0.100	
11-JUN-80		0.52	0.34	0.180	0.070	
24-JUN-80	0.031	0.46	0.41	0.050	0.140	
17-JUL-80	0.033	0.49	0.38	0.110	0.030	
09-SEP-80	0.066	0.45	0.25	0.200	0.005	
22-OCT-80	0.010	0.31	0.24	0.070	0.030	
17-DEC-80	0.013	0.37	0.31	0.070	0.040	
13-JAN-81	0.018	0.50	0.44	0.060	0.200	
23-FEB-81	0.017	0.51	0.49	0.020	0.350	
28-APR-81	0.064	0.71	0.51	0.200	0.240	0.05
26-MAY-81	0.056	0.64	0.42	0.220	0.040	
10-JUN-81	0.048	0.43	0.31	0.120	0.005	0.05
07-JUL-81	0.024	1.10	1.00	0.060		0.05
21-JUL-81	0.049	0.35	0.26	0.090		0.05
19-AUG-81	0.049	0.57	0.47	0.100	0.350	0.05
08-SEP-81		0.47	0.39	0.080	0.170	0.05
22-SEP-81	0.033	0.25	0.18	0.070	0.080	0.05
24-NOV-81	0.014	0.27	0.23	0.040	0.060	0.05
06-JAN-82	0.067	0.32	0.32	0.005		0.05
16-FEB-82	0.030	0.53	0.53	0.005	0.340	0.05

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	P Total	N Total	N Diss	N Part	N NO23	N NH3
11-MAY-82	0.061	0.55	0.46	0.090	0.360	0.05
18-MAY-82	0.049	0.56	0.44	0.120	0.400	0.05
31-MAY-82	0.034	0.53	0.46	0.070	0.290	0.05
14-JUN-82	0.042	0.60	0.45	0.150	0.250	0.05
28-JUN-82	0.032	0.37	0.29	0.080	0.020	0.05
12-JUL-82	0.062	0.52	0.42	0.100	0.080	0.05
19-JUL-82	0.035	0.37	0.26	0.110	0.040	0.05
02-AUG-82	0.062	0.59	0.55	0.040	0.320	0.05
31-AUG-82	0.080	0.45	0.40	0.050	0.130	0.17
18-OCT-82	0.032	0.39	0.26	0.130	0.020	0.05
10-JAN-83	0.150	0.51	0.45	0.060	0.170	0.05
07-MAR-83	0.037	0.54	0.51	0.030	0.350	0.05
16-MAY-83	0.045					0.05
06-JUN-83	0.056					0.05
27-JUN-83	0.032	0.47	0.33	0.140	0.020	0.05
18-JUL-83	0.030	0.27	0.25	0.020	0.060	0.05
08-AUG-83	0.022	0.34	0.31	0.030	0.030	0.05
15-AUG-83	0.027	0.36	0.29	0.070	0.005	0.05
12-SEP-83	0.036	0.40	0.31	0.090	0.010	0.05
03-OCT-83	0.047	0.63	0.39	0.240	0.005	0.05
16-OCT-83	0.047	0.56	0.37	0.190	0.010	0.05
12-DEC-83						
30-JAN-84	0.041	0.72	0.65	0.070	0.320	0.20
05-MAR-84	0.068	0.80	0.77	0.030	0.440	0.30
04-JUN-84	0.037	0.43	0.23	0.200	0.005	0.05
20-JUN-84	0.075	0.42	0.25	0.170	0.005	0.05
25-JUN-84	0.015	0.34	0.24	0.100	0.010	0.05
10-JUL-84	0.035	0.45	0.28	0.170	0.005	0.05
23-JUL-84	0.014	0.71	0.35	0.360	0.005	0.05
20-AUG-84	0.016	0.36	0.28	0.080	0.020	0.05
28-AUG-84	0.025	0.41	0.29	0.120	0.020	0.05

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Carbon DissOrg	Carbon PartOrg	Chlor a	Phenol ug/L	Coli-T no/100 ml	Coli-F no/100 ml
11-JUN-79	5.0	0.07	0.1100	0.0010	28	1
18-JUL-79	5.0	0.59	0.0050			
04-DEC-79	4.0	0.22	0.0005	0.0010	1	1
15-JAN-80	5.0	0.18	0.0005	0.0030	2	2
26-FEB-80	3.0	0.24	0.0060	0.0010	27	2
20-MAR-80	3.0	0.25	0.0020	0.0010	6	6
23-APR-80	3.0	0.40	0.0070	0.0040	4	1
06-MAY-80	3.0	1.10	0.0140	0.0010	2	1
15-MAY-80	4.0	0.67	0.0010	0.0010		1
29-MAY-80	4.0	0.60	0.0020	0.0020	2	1
04-JUN-80	5.0	0.68	0.0090	0.0030	6	3
11-JUN-80	5.0	1.80	0.0005	0.0030	9	2
24-JUN-80	5.0	0.54	0.0020	0.0020	17	4
17-JUL-80	5.0	0.55	0.0040	0.0040		
09-SEP-80	5.0	1.10	0.0120	0.0010	22	14
22-OCT-80	5.0	0.47	0.0040	0.0005	2	1
17-DEC-80	5.0	0.34	0.0005	0.0040	2	2
13-JAN-81	5.0	0.29	0.0010	0.0030	4	1
23-FEB-81	4.0	0.18	0.0005	0.0005		
28-APR-81		1.20	0.0200	0.0020		
26-MAY-81	5.3	1.30		0.0030		10
10-JUN-81	5.6	0.77	0.0050	0.0010	80	80
07-JUL-81	4.5	0.42	0.0030	0.0020	8	1
21-JUL-81	4.5	0.56	0.0010	0.0020	10	6
19-AUG-81	4.1	0.50	0.0030	0.0020	50	4
08-SEP-81	4.9	0.47	0.0040	0.0010		
22-SEP-81	3.6	0.40	0.0090	0.0020		
24-NOV-81	3.6	0.24	0.0020	0.0020	2	2
06-JAN-82	4.3	0.24	0.0040	0.0030		
16-FEB-82	3.8	0.22	0.0020	0.0030	4	4

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Carbon DissOrg	Carbon PartOrg	Chlor a	Phenol ug/L	Coli-T no/100 ml	Coli-F no/100 ml
11-MAY-82	3.4	0.68	0.0080	0.0005		
18-MAY-82	3.2	0.70	0.0100	0.0010		1
31-MAY-82	3.7	0.49	0.0080	0.0010	1	1
14-JUN-82	5.1	0.73	0.0060	0.0030		
28-JUN-82	6.1	0.51	0.0080	0.0030		
12-JUL-82	5.7	0.69	0.0040	0.0010		
19-JUL-82	4.9	0.63	0.0020	0.0020		
02-AUG-82	6.0	0.30	0.0020	0.0005		8
31-AUG-82	6.4	0.28	0.0010	0.0040	28	10
18-OCT-82	5.2	0.87	0.0200	0.0010	2	1
10-JAN-83	4.4	0.72	0.0200	0.0020	40	1
07-MAR-83	3.0	0.20	0.0010	0.0005	10	1
16-MAY-83			0.0100	0.0020	1	1
06-JUN-83			0.0060	0.0040	1	1
27-JUN-83	5.3	0.90	0.0020	0.0040	1	1
18-JUL-83	5.0	0.15	0.0010	0.0040		
08-AUG-83	5.4	0.17	0.0010			
15-AUG-83	6.5	0.45	0.0010	0.0070		
12-SEP-83	5.7	0.51	0.0020	0.0020		
03-OCT-83	7.0	1.20	0.0020	0.0040	40	20
16-OCT-83	6.9	1.00	0.0005	0.0070		
12-DEC-83						
30-JAN-84	4.2	0.46	0.0005	0.0020		2
05-MAR-84	3.3	0.20	0.0005			
04-JUN-84	4.3	0.92	0.0200		1	1
20-JUN-84	5.8	0.80	0.0005		210	136
25-JUN-84	4.6	0.79	0.0010		40	1
10-JUL-84	4.7	0.74	0.0005	0.0010		490
23-JUL-84	6.0	1.60	0.0005	0.0040		4
20-AUG-84	4.9	0.36	0.0005	0.0005		
28-AUG-84	6.1	0.63	0.0030	0.0040		

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Alk-T	Alk-P	Ca	Mg	T-Hard Calc	Bicarb Calc
11-JUN-79	113	0.0	40.1	14.4	159	138
18-JUL-79	130	0.0	42.2	17.3	177	159
04-DEC-79	179	0.0	57.8	21.5	233	218
15-JAN-80	138	0.0	50.0	18.2	200	168
26-FEB-80	165	0.0	53.4	19.8	215	201
20-MAR-80	129	0.0	44.4	17.0	181	157
23-APR-80	140	0.0	46.5	16.0	117	171
06-MAY-80	120	0.0	41.3	13.9	160	146
15-MAY-80	128	0.0	41.5	14.3	162	156
29-MAY-80	152	0.0	45.0	15.8	177	185
04-JUN-80	128	0.0	40.0	14.2	158	156
11-JUN-80	118	0.0	37.4	12.9	147	144
24-JUN-80	124	0.0	39.5	14.3	158	152
17-JUL-80	123	0.0	41.0	13.0	156	150
09-SEP-80	128	0.0	41.0	13.6	158	156
22-OCT-80	147	0.0	45.6	15.4	177	179
17-DEC-80	150	0.0	48.5	16.7	190	183
13-JAN-81	174	0.0	53.9	19.5	215	212
23-FEB-81	162	0.0	50.1	17.2	196	198
28-APR-81	130	0.0	44.0	16.5	178	159
26-MAY-81	122	0.0	37.2	13.3	148	149
10-JUN-81	137	0.0	42.9	14.7	168	167
07-JUL-81	139	0.0	43.6	15.6	173	169
21-JUL-81	137	0.0	43.5	15.1	171	167
19-AUG-81	132	0.0	41.0	14.1	160	161
08-SEP-81	136	0.0	41.0	13.9	160	166
22-SEP-81	137	0.2	42.8	14.8	168	167
24-NOV-81	159	0.0	47.6	16.0	185	194
06-JAN-82	151	0.0	47.3	16.1	184	184
16-FEB-82	160	0.0	52.0	17.9	204	195

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Alk-T	Alk-P	Ca	Mg	T-Hard Calc	Bicarb Calc
11-MAY-82	120	0.0	37.5	13.4	149	146
18-MAY-82	130	0.0	44.1	14.3	169	158
31-MAY-82	115	0.0	36.5	12.1	141	140
14-JUN-82	110	1.0	35.5	10.9	134	132
28-JUN-82	120	0.0	38.6	13.4	152	146
12-JUL-82	130	0.0	41.3	13.8	160	158
19-JUL-82	135	0.0	41.1	13.9	160	165
02-AUG-82	122	0.0	39.1	12.5	149	148
31-AUG-82	115	0.0	37.2	12.3	144	140
18-OCT-82	140	2.5	44.0	14.0	168	165
10-JAN-83	175	0.0	52.3	17.4	202	213
07-MAR-83	155	0.0	48.1	16.5	188	189
16-MAY-83	125	0.0	37.1	12.8	145	152
06-JUN-83	140	0.0	40.8	14.5	162	171
27-JUN-83	145	0.0	42.1	14.8	166	177
18-JUL-83	135	0.0	41.9	15.1	167	165
08-AUG-83	140	0.0	42.0	15.8	170	171
15-AUG-83	175	0.0	46.4	19.4	196	213
12-SEP-83	225	0.0	58.7	22.3	238	274
03-OCT-83	220	0.0	57.6	22.0	234	268
16-OCT-83	170	0.0	47.9	17.6	192	207
12-DEC-83						
30-JAN-84	164	0.0	51.0	18.4	203	200
05-MAR-84	176	0.0	53.3	19.2	212	215
04-JUN-84	146	0.0	39.8	13.2	154	178
20-JUN-84	219	0.0	53.6	18.8	211	267
25-JUN-84		0.0	41.3	14.8	164	
10-JUL-84		0.0	45.0	17.4	184	
23-JUL-84	193	0.0	45.4	19.5	194	235
20-AUG-84	239	0.0	50.0	21.1	212	291
28-AUG-84	280	0.0	54.6	26.2	244	341

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	SO4	Cl	SiO2	F	Na	K
					mg/L	
11-JUN-79	67.0	5.7	1.8	0.11	16.0	3.3
18-JUL-79	62.0	7.4	1.4	0.13	21.0	3.0
04-DEC-79	65.0	15.0	1.5	0.15	26.0	2.9
15-JAN-80	67.0	11.0	0.9	0.17	19.0	2.2
26-FEB-80	64.0	9.2	3.9	0.15	21.0	2.4
20-MAR-80	59.0	8.8	3.1	0.16	21.0	2.3
23-APR-80	55.0	7.1	3.4	0.13	19.0	1.9
06-MAY-80	53.0	8.7	2.4	0.12	17.0	2.0
15-MAY-80	51.0	9.2	1.4	0.10	16.0	2.2
29-MAY-80	46.0	11.0	3.0	0.14	20.0	2.7
04-JUN-80	44.0	8.2	1.0	0.10	18.0	3.0
11-JUN-80	49.0	5.8	0.4	0.11	17.0	2.9
24-JUN-80	51.0	6.5	2.0	0.12	17.0	2.8
17-JUL-80	40.0	3.6	4.8	0.13	11.0	1.9
09-SEP-80	40.0	4.3	0.3	0.08	13.0	1.9
22-OCT-80	47.0	7.4	0.9	0.16	16.0	1.9
17-DEC-80	54.0	7.3	0.6		19.0	2.1
13-JAN-81	67.0	9.1	1.9	0.18	23.0	2.7
23-FEB-81	66.0	8.1	3.3	0.18	21.0	2.5
28-APR-81	52.0	8.9	3.1	0.15	24.0	3.0
26-MAY-81	44.0	6.7	1.0	0.18	18.0	3.1
10-JUN-81	44.0	6.4	1.2	0.13	17.0	2.9
07-JUL-81	47.0	5.3	1.3	0.15	16.0	2.2
21-JUL-81	48.0	3.4	1.9	0.15	16.0	2.2
19-AUG-81	41.0	3.2	5.1	0.14	12.0	1.9
08-SEP-81	40.0	3.3	4.8	0.13	13.0	1.9
22-SEP-81	40.0	3.9	4.0	0.13	13.0	1.8
24-NOV-81	46.0	7.4	2.0	0.07	17.0	1.8
06-JAN-82	52.0	6.9	1.6	0.20	16.0	1.8
16-FEB-82	58.0	7.7	3.6	0.15	17.0	2.1

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	SO4	Cl	SiO2	F	Na	K
					mg/L	
11-MAY-82	46.0	7.9	2.6	0.10	15.0	1.8
18-MAY-82	50.0	7.9	3.0	0.15	15.0	1.8
31-MAY-82	42.0	7.4	2.5	0.15	13.0	1.8
14-JUN-82	42.0	6.9	1.5	0.12	14.0	2.6
28-JUN-82	46.0	5.7	0.5	0.10	16.0	3.2
12-JUL-82	50.0	6.7	1.6	0.17	17.0	3.2
19-JUL-82	48.0	5.8	1.4	0.17	15.0	2.6
02-AUG-82	36.0	4.0	4.2	0.15	11.0	2.3
31-AUG-82	36.0	4.3	5.0	0.13	10.0	2.2
18-OCT-82	47.0	6.0	0.1	0.15	15.0	2.3
10-JAN-83	59.0	10.0	1.6	0.15	22.0	2.8
07-MAR-83	52.0	6.8	3.4	0.08	18.0	2.3
16-MAY-83	46.0	6.7	3.6	0.09	16.0	2.7
06-JUN-83	42.0	9.3	1.2	0.16	18.0	2.8
27-JUN-83	44.0	9.8	2.2	0.11	19.0	2.6
18-JUL-83	47.0	6.3	1.8	0.12	15.0	2.3
08-AUG-83	57.0	7.8	2.9	0.13	20.0	2.7
15-AUG-83	53.0	11.0	3.1	0.18	23.0	3.0
12-SEP-83	41.0	13.0	3.9	0.11	24.0	3.1
03-OCT-83	47.0	12.0	2.2	0.11	26.0	3.7
16-OCT-83	55.0	14.0	2.8	0.16	27.0	3.1
12-DEC-83						
30-JAN-84	72.1	11.8	1.1	0.25	24.5	2.7
05-MAR-84	68.1	10.6	2.8	0.26	19.1	2.6
04-JUN-84	43.0	8.2	0.5	0.15	16.7	2.5
20-JUN-84	41.9	13.5	3.8	0.15	21.6	2.6
25-JUN-84	65.7	10.6	1.6	0.13	20.1	2.7
10-JUL-84	58.8	29.4	1.4	0.15	24.0	3.1
23-JUL-84	61.2	14.8	1.0	0.14	26.5	3.2
20-AUG-84	44.4	18.4	4.0	0.15	27.0	3.3
28-AUG-84	38.2	24.4	4.1	0.13	32.5	2.9

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Arsenic Diss	Iron Ext	Mn Ext	Copper Total	Lead Total
11-JUN-79	0.00025	0.16	0.019	0.0030	0.0020
18-JUL-79	0.00100	0.07	0.012	0.0010	0.0020
04-DEC-79	0.00070	0.21	0.210	0.0010	0.0020
15-JAN-80	0.00050				
26-FEB-80	0.00050				
20-MAR-80	0.00025				
23-APR-80	0.00050	0.02	0.005	0.0020	0.0020
06-MAY-80	0.00025	0.02	0.005	0.0040	0.0020
15-MAY-80	0.00070	0.02	0.005	0.0020	0.0020
29-MAY-80	0.00080	0.02	0.005	0.0040	0.0020
04-JUN-80	0.00050	0.02	0.005	0.0030	0.0020
11-JUN-80	0.00025	0.02	0.005		0.0050
24-JUN-80	0.00100			0.0030	0.0020
17-JUL-80	0.00090			0.0020	0.0020
09-SEP-80	0.00090			0.0040	0.0020
22-OCT-80	0.00100			0.0060	0.0020
17-DEC-80	0.00070				
13-JAN-81	0.00050			0.0005	0.0020
23-FEB-81	0.00025			0.0010	0.0020
28-APR-81	0.00080	0.27	0.020	0.0030	0.0020
26-MAY-81	0.00025			0.0010	0.0020
10-JUN-81	0.00025	0.12	0.030	0.0030	0.0020
07-JUL-81	0.00090	0.10	0.050	0.0030	0.0020
21-JUL-81	0.00150	0.11	0.040	0.0020	0.0020
19-AUG-81	0.00100	0.21	0.040	0.0005	0.0020
08-SEP-81	0.00100	0.12	0.010	0.0005	0.0020
22-SEP-81	0.00120	0.10	0.010	0.0070	0.0020
24-NOV-81	0.00050	0.07	0.060	0.0010	0.0020
06-JAN-82	0.00050	0.05	0.230	0.0070	0.0020
16-FEB-82	0.00080	0.08	0.020	0.0030	0.0040

DRAGLINE CHANNEL BELOW CONTROL STRUCTURE

Date	Arsenic Diss	Iron Ext	Mn Ext	Copper Total	Lead Total
11-MAY-82	0.00060	0.19	0.030	0.0090	0.0020
18-MAY-82	0.00060	0.22	0.040	0.0010	0.0020
31-MAY-82	0.00025	0.22	0.030	0.0020	0.0020
14-JUN-82	0.00025	0.09	0.020	0.0060	0.0020
28-JUN-82	0.00025	0.14	0.020	0.0020	0.0050
12-JUL-82	0.00050	0.22	0.030	0.0030	0.0020
19-JUL-82	0.00080	0.08	0.030	0.0020	0.0020
02-AUG-82	0.00080	0.20	0.030	0.0020	0.0020
31-AUG-82	0.00070	0.07	0.020	0.0020	0.0020
18-OCT-82	0.00080	0.07	0.020	0.0020	0.0020
10-JAN-83	0.00050	0.05	0.020	0.0010	0.0020
07-MAR-83	0.00070	0.02	0.010	0.0020	0.0020
16-MAY-83	0.00050	0.16	0.020	0.0020	0.0020
06-JUN-83	0.00025	0.17	0.080	0.0020	0.0020
27-JUN-83	0.00070	0.31	0.100	0.0020	0.0020
18-JUL-83	0.00090	0.18	0.020	0.0010	0.0020
08-AUG-83	0.00130	0.17	0.070	0.0010	0.0020
15-AUG-83					
12-SEP-83	0.00250			0.0020	0.0020
03-OCT-83	0.00060	0.65	0.170	0.0030	0.0020
16-OCT-83	0.00200	0.02	0.005	0.0020	0.0020
12-DEC-83					
30-JAN-84	0.00120				
05-MAR-84	0.00100	0.02	0.010	0.0005	0.0005
04-JUN-84	0.00060	0.10	0.120	0.0020	0.0005
20-JUN-84	0.00070	0.18	0.280	0.0010	0.0005
25-JUN-84	0.00060	0.17	0.090	0.0010	0.0010
10-JUL-84	0.00070	0.11	0.050	0.0010	0.0005
23-JUL-84	0.00110	0.09	0.060	0.0005	0.0005
20-AUG-84	0.00080	0.12	0.080	0.0040	0.0005
28-AUG-84	0.00090	0.21	0.100	0.0120	0.0005

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Julian Sum	Julian Date	Oxygen Diss	pH Lab	pH Field	Spec Cond (L)
11-JUN-79	162	162		7.7	8.0	485
18-JUL-79	166	199		7.9		558
27-AUG-79	239	239		7.9	7.7	544
04-DEC-79	338	338	10.1	7.8	7.8	622
15-JAN-80	380	15	7.5	7.3	7.6	
05-MAY-80	491	126	8.7	7.7	8.0	491
15-MAY-80	501	136	9.8	7.9	8.3	595
29-MAY-80	515	150	9.1	8.6	8.6	514
04-JUN-80	521	156	10.6	8.7	8.7	567
11-JUN-80	528	163	9.5	8.4	8.1	589
24-JUN-80	541	176		8.2	8.2	655
17-JUL-80	564	199	8.2	8.2	8.6	516
09-SEP-80	618	253		7.8	7.8	604
21-OCT-80	660	295	11.8	7.8	8.0	752
16-DEC-80	716	351		7.6		816
12-JAN-81	743	12		7.1	7.2	894
23-FEB-81	785	54	6.4	7.0	7.0	1158
27-APR-81	848	117	10.2	7.2	7.4	801
26-MAY-81	877	146		8.0	7.8	901
10-JUN-81	892	161	7.3	8.0	7.3	591
07-JUL-81	919	188	6.9	8.1	8.1	668
21-JUL-81	933	202	8.3	8.0	8.0	620
19-AUG-81	962	231	7.5	8.0	8.0	745
08-SEP-81	982	251	7.4	7.9	7.9	533
21-SEP-81	995	264	7.2	8.4	8.5	560
23-NOV-81	1058	327	11.8	7.5	7.6	513
15-FEB-82	1142	46	4.6	7.1	7.6	632
10-MAY-82	1226	130	10.4	7.5		611
18-MAY-82	1234	138	9.6	7.5		480
31-MAY-82	1247	151		7.6		469

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Julian Sum	Julian Date	Oxygen Diss	pH Lab	pH Field	Spec Cond (L)
14-JUN-82	1261	165		7.8		488
28-JUN-82	1275	179		7.5	6.9	522
12-JUL-82	1289	193		8.0	7.7	561
19-JUL-82	1296	200	8.0	7.9	6.7	567
02-AUG-82	1310	214	8.3	7.5	7.1	460
31-AUG-82	1339	243	10.6	7.6		494
18-OCT-82	1387	291	14.0	7.9		493
10-JAN-83	1471	10	4.5	7.3	6.8	585
07-MAR-83	1527	66	8.3	7.2		927
16-MAY-83	1597	136	11.0	7.6	7.8	870
06-JUN-83	1618	157	9.0	7.7	8.1	807
27-JUN-83	1639	178	11.0	8.1	8.0	728
18-JUL-83	1660	199	9.0	7.5	7.6	511
08-AUG-83	1681	220	7.0	7.7		500
15-AUG-83	1688	227	10.1	7.7	7.1	513
12-SEP-83	1716	255	9.5	7.9		537
03-OCT-83	1737	276	8.9	7.8	7.8	607
16-OCT-83	1781	320	9.8	7.8	8.3	606
12-DEC-83	1807	346				
30-JAN-84	1856	30	5.7	7.4		635
05-MAR-84	1891	65	4.8	7.6		639
04-JUN-84	1982	156	7.8	8.0		512
19-JUN-84	1997	171	7.6	8.0		569
25-JUN-84	2003	177	7.1	7.8		503
10-JUL-84	2018	192		7.9	7.2	400
23-JUL-84	2031	205	9.8	7.7	7.5	440
21-AUG-84	2060	234	8.0	7.8	7.7	442
28-AUG-84	2067	241	7.1	7.9	7.1	841

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Spec Cond (F)	Turb Lab	Colour Apparent	Temp Field	T.D.S. Calc	N.F.R. 105 C
11-JUN-79	490	1.7	40		248	2.0
18-JUL-79	550	2.8	40		283	0.5
27-AUG-79	520	1.0	40	18.0	271	2.0
04-DEC-79	510	1.1	30	3.0	290	1.0
15-JAN-80	725	3.6	100	0.0	416	11.0
05-MAY-80	400	3.6	50	16.7	257	7.0
15-MAY-80	550	1.8	30	10.0	255	2.0
29-MAY-80	475	3.6	50	15.0	261	3.0
04-JUN-80	450	3.1	60	12.0	275	7.0
11-JUN-80	450	3.5	60	20.0	278	6.0
24-JUN-80	550	2.5	40	20.0	321	4.0
17-JUL-80	460	1.5	40	16.0	251	3.0
09-SEP-80	500	2.9	50	14.0	313	4.0
21-OCT-80		4.4	50	5.0	409	7.0
16-DEC-80		4.1	100	1.0	330	7.0
12-JAN-81		12.0	30	1.0	478	15.0
23-FEB-81		44.0		1.5	611	32.0
27-APR-81	790	6.1	30	2.0	437	7.0
26-MAY-81	850	3.6	30	7.0	480	6.0
10-JUN-81	510	1.5	20	8.0	301	3.0
07-JUL-81	575	1.2	30	16.0	304	2.0
21-JUL-81	620	1.4	30	20.0	319	1.0
19-AUG-81	770	2.5	50	22.0	368	2.0
08-SEP-81	500	1.8	40	13.0	266	3.0
21-SEP-81	530	2.4	50	13.0	277	7.0
23-NOV-81	500	1.5	50	2.0	292	5.0
15-FEB-82	650	4.0	140	1.0	374	14.0
10-MAY-82	610	6.4	70	3.0	340	8.0
18-MAY-82	460	2.1	30	10.0	248	4.0
31-MAY-82	480	1.5	30	10.0	254	1.0

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Spec Cond (F)	Turb Lab	Colour Apparent	Temp Field	T.D.S. Calc	N.F.R. 105 C
14-JUN-82	510	1.3	40	17.0	265	1.0
28-JUN-82	460	1.4	40		287	4.0
12-JUL-82	610	0.8	40		310	2.0
19-JUL-82	640	1.3	50	18.0	323	1.0
02-AUG-82	450	1.2	40	15.0	246	2.0
31-AUG-82	515	1.7	30	10.0	267	2.0
18-OCT-82		1.2	30	3.0	286	2.0
10-JAN-83		2.2	30	1.0	331	3.0
07-MAR-83		25.0	240	0.5	361	20.0
16-MAY-83	620	7.8	50	4.0	464	11.0
06-JUN-83		3.0	60	15.0	431	2.0
27-JUN-83	695	3.0	60	19.0	380	1.0
18-JUL-83	524	1.3	50	19.0	264	3.0
08-AUG-83	518	2.5	70	23.0	258	3.0
15-AUG-83	554	3.5	60	15.0	277	5.0
12-SEP-83	440	1.8	50	18.5	277	2.0
03-OCT-83	453	2.1	50	8.0	322	2.0
16-OCT-83	441	2.5	50	5.5	325	2.0
12-DEC-83						
30-JAN-84	352	1.6	40	0.0	325	3.0
05-MAR-84	403	14.0		0.0	336	13.0
04-JUN-84	471	1.8	50	5.0	271	0.5
19-JUN-84	528	1.8	40	20.0	295	3.0
25-JUN-84	451	2.5	60	20.0		4.0
10-JUL-84	379	1.8	60	20.0		2.0
23-JUL-84	425	1.5	50	22.0	218	57.0
21-AUG-84	380	5.0	50	20.0	243	14.0
28-AUG-84	710	2.2	30	20.0	414	2.0

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	P Total	N Total	N Diss	N Part	N NO23	N NH3
11-JUN-79	0.028	0.75		0.06	0.050	0.20
18-JUL-79	0.011	0.62		0.08	0.005	0.05
27-AUG-79	0.014	0.77		0.09	0.005	0.05
04-DEC-79	0.023	1.00		0.08	0.030	0.12
15-JAN-80	0.063	1.80	1.50	0.27	0.020	
05-MAY-80	0.057	1.10	0.77	0.28	0.005	
15-MAY-80	0.034	0.79	0.65	0.14	0.005	
29-MAY-80	0.029	0.97	0.88	0.09	0.010	
04-JUN-80	0.039	1.10	1.00	0.14	0.020	
11-JUN-80	0.047	1.20	1.10	0.12	0.005	
24-JUN-80	0.031	1.10	1.00	0.10	0.005	
17-JUL-80	0.034	1.30	1.10	0.16	0.005	
09-SEP-80	0.028	0.71	0.62	0.09	0.010	
21-OCT-80	0.042	1.10	0.79	0.33	0.010	
16-DEC-80	0.038	1.60	1.40	0.17	0.010	
12-JAN-81	0.082	1.80	1.40	0.41	0.010	
23-FEB-81	0.270	2.90	2.30	0.55	0.005	
27-APR-81		1.50	1.20	0.25	0.010	0.25
26-MAY-81	0.029	1.10	0.96	0.13	0.005	0.05
10-JUN-81	0.021	0.97	0.86	0.11	0.005	0.05
07-JUL-81	0.009	0.95	0.89	0.06	0.005	0.05
21-JUL-81	0.028	1.10	0.94	0.14		0.05
19-AUG-81	0.049	1.00	0.83	0.19	0.020	0.05
08-SEP-81	0.029	0.91	0.79	0.12	0.010	0.05
21-SEP-81	0.033	1.10	1.00	0.10	0.010	0.05
23-NOV-81	0.046	0.59	0.47	0.12	0.010	0.05
15-FEB-82	0.340	1.20	0.90	0.30	0.005	0.05
10-MAY-82	0.190	0.92	0.72	0.20	0.010	0.05
18-MAY-82	0.048	0.60	0.45	0.15	0.005	0.05
31-MAY-82	0.032	0.52	0.46	0.06	0.010	0.05

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	P Total	N Total	N Diss	N Part	N NO23	N NH3
14-JUN-82	0.031	0.66	0.57	0.09	0.005	0.05
28-JUN-82	0.049	0.74	0.65	0.09	0.005	0.30
12-JUL-82	0.070	1.00	0.93	0.07	0.005	0.05
19-JUL-82	0.036	0.91	0.83	0.08	0.010	0.05
02-AUG-82	0.055	0.61	0.50	0.11	0.010	0.05
31-AUG-82	0.039	0.56	0.48	0.08	0.100	0.14
18-OCT-82	0.041	0.65	0.55	0.10	0.005	0.05
10-JAN-83	0.076	0.88	0.78	0.10	0.020	0.30
07-MAR-83	0.280	1.40	1.10	0.30	0.005	0.70
16-MAY-83	0.096					0.05
06-JUN-83	0.120				0.010	0.05
27-JUN-83	0.040	0.79	0.76	0.03	0.010	0.05
18-JUL-83	0.043	0.82	0.78	0.04	0.010	0.05
08-AUG-83	0.043	1.00	0.89	0.11	0.005	0.05
15-AUG-83	0.070	1.00	0.87	0.15	0.010	0.05
12-SEP-83	0.046	1.10	1.00	0.13	0.020	0.10
03-OCT-83	0.040	1.20	1.10	0.13	0.050	0.40
16-OCT-83	0.033	1.30	1.10	0.17	0.070	0.30
12-DEC-83						
30-JAN-84	0.070	1.20	1.10	0.13	0.200	0.50
05-MAR-84	0.350	1.60	1.10	0.51	0.005	1.30
04-JUN-84	0.021	0.71	0.63	0.08	0.005	0.05
19-JUN-84	0.060	0.88	0.77	0.11	0.005	0.05
25-JUN-84	0.032	0.86	0.72	0.14	0.020	0.05
10-JUL-84	0.034	0.86	0.77	0.09	0.005	0.05
23-JUL-84	0.009	0.72	0.62	0.10	0.005	0.05
21-AUG-84	0.024	0.73	0.61	0.12	0.005	0.05
28-AUG-84	0.020	0.76	0.67	0.09	0.005	0.05

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Carbon DissOrg	Carbon PartOrg	Chlor a	Phenol ug/L	Coli-T no/100 ml	Coli-F no/100 ml
11-JUN-79	13.0	0.32	0.0030	0.0010	8	0
18-JUL-79	14.0	0.54	0.0005			
27-AUG-79	14.0	0.41	0.0030	0.0005	10	2
04-DEC-79	15.0	0.39	0.0030	0.0010	0	0
15-JAN-80	22.0	1.70	0.0005	0.0040	4	0
05-MAY-80	13.0	1.60	0.0060	0.0020	6	2
15-MAY-80	12.0	0.54	0.0020	0.0010	1050	0
29-MAY-80	16.0	0.64	0.0030	0.0020	2	0
04-JUN-80	18.0	0.97	0.0005	0.0020	48	36
11-JUN-80	19.0	0.84	0.0005	0.0030	2	2
24-JUN-80	17.0	0.67	0.0050	0.0030	13	0
17-JUL-80	18.0	0.90	0.0050	0.0040		
09-SEP-80	10.0	0.56	0.0010	0.0020		
21-OCT-80	13.0	1.70	0.0030	0.0020	2	0
16-DEC-80	18.0	1.00	0.0005	0.0040	0	0
12-JAN-81	18.0	2.80	0.0080	0.0060	9	0
23-FEB-81	25.0	5.60	0.0020	0.0050		
27-APR-81		1.60	0.0080	0.0060		
26-MAY-81	16.0	0.83	0.0040	0.0030		10
10-JUN-81	16.0	0.62	0.0040	0.0020	0	0
07-JUL-81	18.0	0.41	0.0010	0.0030	0	0
21-JUL-81	18.0	0.91	0.0010	0.0030	0	0
19-AUG-81	14.0	0.86	0.0080	0.0030	50	26
08-SEP-81	14.0	0.66	0.0050	0.0030		
21-SEP-81	4.1	0.66	0.0080	0.0050		
23-NOV-81	9.2	0.79	0.0020	0.0020		2
15-FEB-82	14.0	1.70	0.0060	0.0060	4	2
10-MAY-82	18.0	1.30	0.0060	0.0020		
18-MAY-82	10.0	0.99	0.0100	0.0020		2
31-MAY-82	12.0	0.42	0.0020	0.0010		4

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Carbon DissOrg	Carbon PartOrg	Chlor a	Phenol ug/L	Coli-T no/100 ml	Coli-F no/100 ml
14-JUN-82	12.0	0.46	0.0010	0.0020		
28-JUN-82	16.0	0.67	0.0020	0.0010		
12-JUL-82	16.0	0.48	0.0080	0.0020		
19-JUL-82	18.0	0.52	0.0030	0.0030		
02-AUG-82	9.6	0.67	0.0040	0.0040	18	14
31-AUG-82	8.9	0.58	0.0040	0.0040	2	0
18-OCT-82	9.9	0.64	0.0050	0.0030	0	0
10-JAN-83	12.0	0.62	0.0040	0.0040	0	0
07-MAR-83	19.0	1.90	0.0030	0.0050	12	6
16-MAY-83			0.0300	0.0090	0	0
06-JUN-83			0.0040	0.0080	0	0
27-JUN-83	16.0	0.24	0.0020	0.0090	0	0
18-JUL-83	16.0	0.30	0.0010	0.0090		
08-AUG-83	18.0	0.67	0.0080			
15-AUG-83	21.0	0.97	0.0040	0.0090		
12-SEP-83	19.0	0.94	0.0100	0.0050		
03-OCT-83	20.0	0.79	0.0020	0.0050	300	56
16-OCT-83	18.0	1.00	0.0010	0.0060		
12-DEC-83						
30-JAN-84	19.0	0.74	0.0005	0.0030	1	1
05-MAR-84	16.0	3.20	0.0030	0.0060		
04-JUN-84	14.0	0.50	0.0005		10	1
19-JUN-84	4.9	0.44	0.0005		1	1
25-JUN-84	16.0	0.83	0.0030		2	1
10-JUL-84	12.0	0.45	0.0005	0.0040	20	4
23-JUL-84	15.0	0.65	0.0070	0.0040	2000	2
21-AUG-84	17.0	0.75	0.0040	0.0040		
28-AUG-84	14.0	0.32	0.0005	0.0020		

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Alk-T	Alk-P	Ca	Mg	T-Hard Calc	Bicarb Calc
11-JUN-79	117	0.0	48.7	16.1	183	143
18-JUL-79	138	0.0	44.9	18.4	188	168
27-AUG-79	119	0.0	36.8	19.0	170	145
04-DEC-79	179	0.0	50.5	21.5	216	218
15-JAN-80	250	0.0	70.5	29.3	297	305
05-MAY-80	160	0.0	46.4	16.8	185	195
15-MAY-80	145	0.0	48.3	17.7	194	177
29-MAY-80	145		40.9	18.5	178	177
04-JUN-80	137	3.9	39.3	19.9	180	158
11-JUN-80	139	17.4	42.3	20.6	191	127
24-JUN-80	147	0.0	46.0	22.2	206	179
17-JUL-80	133	0.0	33.0	19.8	164	162
09-SEP-80	149	0.0	44.1	19.6	191	182
21-OCT-80	169	0.0	71.0	23.6	275	206
16-DEC-80	218	0.0	74.5	28.1	302	266
12-JAN-81	248	0.0	78.0	29.4	316	302
23-FEB-81	345	0.0	95.3	41.2	408	421
27-APR-81	238	0.0	75.5	31.0	316	290
26-MAY-81	223	0.0	82.0	30.0	328	272
10-JUN-81	152	0.0	59.6	20.4	233	185
07-JUL-81	140	0.0	55.7	24.4	240	171
21-JUL-81	152	0.0	54.0	26.0	242	185
19-AUG-81	126	0.0	37.8	22.0	185	154
08-SEP-81	137	0.0	35.4	18.2	163	167
21-SEP-81	156	0.2	34.9	23.1	182	190
23-NOV-81	159	0.0	47.9	19.1	198	194
15-FEB-82	220	0.0	63.2	24.6	259	268
10-MAY-82	210	0.0	49.3	23.6	220	256
18-MAY-82	145	0.0	42.8	15.1	169	177
31-MAY-82	165	0.0	44.9	16.1	178	201

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Alk-T	Alk-P	Ca	Mg	T-Hard Calc	Bicarb Calc
14-JUN-82	165	0.0	45.9	16.5	183	201
28-JUN-82	180	0.0	48.0	20.1	203	219
12-JUL-82	185	0.0	48.8	21.2	209	226
19-JUL-82	200	0.0	49.2	22.1	214	244
02-AUG-82	130	0.0	34.6	17.1	157	159
31-AUG-82	135	0.0	35.4	18.2	163	165
18-OCT-82	155	0.0	40.8	19.0	180	189
10-JAN-83	200	0.0	52.2	22.7	224	244
07-MAR-83	330	0.0	84.5	37.5	365	402
16-MAY-83	305	0.0	76.6	31.0	319	372
06-JUN-83	280	0.0	71.7	29.0	299	341
27-JUN-83	250	0.0	62.8	25.5	262	305
18-JUL-83	145	0.0	36.3	18.5	167	177
08-AUG-83	135	0.0	31.3	18.8	156	165
15-AUG-83	140	0.0	32.2	19.7	162	171
12-SEP-83	150	0.0	34.9	19.5	167	183
03-OCT-83	180	0.0	41.3	21.8	193	219
16-OCT-83	180	0.0	43.1	22.4	200	219
12-DEC-83						
30-JAN-84	188	0.0	44.7	21.1	198	229
05-MAR-84	202	0.0	50.2	23.4	222	246
04-JUN-84	182	0.0	47.1	16.4	185	221
19-JUN-84	168	0.0	39.8	17.9	173	205
25-JUN-84		0.0	36.1	16.5	158	
10-JUL-84		0.0	33.8	13.6	140	
23-JUL-84	138	0.0	31.8	15.2	142	169
21-AUG-84	160	0.0	30.5	16.6	145	195
28-AUG-84	134	0.0	37.7	18.8	172	163

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	SO4	Cl	SiO2	F	Na	K
11-JUN-79	22.0	50.0	2.0	0.09	26.0	4.3
18-JUL-79	15.0	76.0	3.8	0.11	39.0	3.6
27-AUG-79	11.0	82.0	4.8	0.10	43.0	3.2
04-DEC-79	11.0	66.0	5.3	0.13	39.0	5.1
15-JAN-80	11.0	88.0	9.4	0.16	52.0	6.0
05-MAY-80	5.0	55.0	2.8	0.10	31.0	4.3
15-MAY-80	12.0	41.0	1.0	0.08	44.0	4.0
29-MAY-80	10.0	65.0	2.0	0.13	34.0	3.8
04-JUN-80	10.0	78.0	1.8	0.14	40.0	3.5
11-JUN-80	11.0	73.0	1.4	0.12	42.0	3.8
24-JUN-80	10.8	100.0	2.2	0.11	47.0	4.4
17-JUL-80	17.0	58.0	3.8	0.14	35.0	4.1
09-SEP-80	27.0	80.0	2.3	0.09	46.0	4.3
21-OCT-80	91.0	71.0	1.8	0.16	42.0	6.7
16-DEC-80	52.0	84.0	4.7		49.0	6.9
12-JAN-81	57.0	93.0	6.3	0.16	58.0	7.4
23-FEB-81	47.0	130.0	9.3	0.22	72.0	9.4
27-APR-81	35.0	86.0	7.7	0.16	51.0	8.0
26-MAY-81	56.0	113.0	2.8	0.17	55.0	6.7
10-JUN-81	14.0	81.0	2.1	0.09	27.0	5.3
07-JUL-81	21.0	84.0	1.3	0.12	28.0	5.5
21-JUL-81	19.0	88.0	2.2	0.12	33.0	5.4
19-AUG-81	11.0	140.0	1.9	0.14	75.0	4.8
08-SEP-81	24.0	61.0	3.2	0.11	38.0	4.2
21-SEP-81	10.0	69.0	1.6	0.14	40.0	5.0
23-NOV-81	43.0	46.0	3.0	0.08	33.0	4.2
15-FEB-82	44.0	57.0	6.4	0.15	40.0	6.1
10-MAY-82	9.0	76.0	6.2	0.11	44.0	5.6
18-MAY-82	11.0	56.0	1.4	0.12	30.0	4.8
31-MAY-82	12.0	50.0	1.3	0.12	26.0	4.9

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	SO4	Cl	SiO2	F	Na	K
14-JUN-82	13.0	54.0	0.8	0.11	30.0	5.4
28-JUN-82	10.0	58.0	2.0	0.14	35.0	5.6
12-JUL-82	9.4	70.0	3.6	0.15	40.0	5.9
19-JUL-82	9.2	70.0	5.3	0.17	41.0	6.1
02-AUG-82	24.0	51.0	2.5	0.16	36.0	2.6
31-AUG-82	29.0	63.0	2.6	0.13	34.0	3.0
18-OCT-82	25.0	57.0	2.5	0.14	44.0	4.1
10-JAN-83	26.0	62.0	2.9	0.15	40.0	5.3
07-MAR-83	24.0		9.2			8.0
16-MAY-83	9.2	90.0	12.0	0.13	55.0	7.2
06-JUN-83	11.0	84.0	10.0	0.19	50.0	6.9
27-JUN-83	5.6	76.0	6.2	0.13	47.0	6.2
18-JUL-83	5.2	68.0	4.4	0.11	40.0	4.0
08-AUG-83	4.8	67.0	8.7	0.13	42.0	3.9
15-AUG-83	6.0	75.0	11.0	0.13	45.0	4.2
12-SEP-83		75.0	8.2	0.11	44.0	4.9
03-OCT-83	9.0	80.0	8.8	0.10	47.0	5.3
16-OCT-83	9.4	84.0	8.9	0.12	44.0	4.8
12-DEC-83						
30-JAN-84	11.9	76.2	5.6	0.17	46.9	5.2
05-MAR-84	13.0	71.2	4.8	0.17	47.1	5.2
04-JUN-84	9.9	50.5	2.0	0.10	30.5	5.7
19-JUN-84	14.0	73.0	1.4	0.13	42.9	5.5
25-JUN-84	10.2	131.2	3.3	0.10	34.9	4.4
10-JUL-84	8.4	81.8	2.1	0.10	23.6	4.1
23-JUL-84	9.5	41.9	2.5	0.11	29.9	3.9
21-AUG-84	7.7	53.0	3.8	0.13	31.9	3.2
28-AUG-84	9.2	171.1	4.2	0.12	89.3	3.1

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Arsenic Diss	Iron Ext	Mn Ext	Copper Total	Lead Total
11-JUN-79	0.00025	0.46	0.069	0.0005	0.0020
18-JUL-79	0.00090	0.36	0.017	0.0005	0.0020
27-AUG-79	0.00070	0.33	0.049	0.0005	0.0020
04-DEC-79	0.00025	0.32	0.160	0.0005	0.0020
15-JAN-80	0.00025	3.00	0.750	0.0030	0.0020
05-MAY-80	0.00025	0.05	0.005	0.0020	0.0020
15-MAY-80	0.00025	0.02	0.005	0.0020	0.0020
29-MAY-80	0.00025	0.02	0.005	0.0030	0.0020
04-JUN-80	0.00025	0.02	0.005	0.0020	0.0020
11-JUN-80	0.00025	0.02	0.005	0.0130	0.0080
24-JUN-80	0.00080			0.0020	0.0020
17-JUL-80	0.00100			0.0010	0.0020
09-SEP-80	0.00025			0.0020	0.0020
21-OCT-80	0.00050			0.0005	0.0020
16-DEC-80	0.00025	1.00	0.460		
12-JAN-81	0.00025	3.70	0.700	0.0040	0.0020
23-FEB-81	0.00025				
27-APR-81	0.00050			0.0040	0.0020
26-MAY-81	0.00025	0.17	0.540	0.0020	0.0020
10-JUN-81	0.00025	0.17	0.050	0.0020	0.0020
07-JUL-81	0.00050	0.15	0.040	0.0020	0.0020
21-JUL-81	0.00025	0.16	0.050	0.0005	0.0020
19-AUG-81		0.45	0.070	0.0005	0.0020
08-SEP-81	0.00080	0.35	0.040	0.0005	0.0020
21-SEP-81	0.00050	0.28	0.040	0.0090	0.0020
23-NOV-81	0.00050	0.20	0.210	0.0005	0.0020
15-FEB-82	0.00100	3.50	1.100	0.0005	0.0020
10-MAY-82	0.00050	2.50	0.560	0.0030	0.0020
18-MAY-82	0.00025	0.57	0.070	0.0010	0.0020
31-MAY-82	0.00025	0.40	0.050	0.0010	0.0020

BIRCH RIVER BELOW CUMBERLAND MARSHES DAM

Date	Arsenic Diss	Iron Ext	Mn Ext	Copper Total	Lead Total
14-JUN-82	0.00025	0.25	0.050	0.0040	0.0020
28-JUN-82	0.00025	0.82	0.080	0.0005	0.0020
12-JUL-82	0.00025	0.36	0.040	0.0005	0.0020
19-JUL-82	0.00050	0.36	0.040	0.0020	0.0020
02-AUG-82	0.00050	0.42	0.140	0.0005	0.0020
31-AUG-82	0.00025	0.53	0.050	0.0010	0.0020
18-OCT-82	0.00025	0.20	0.030	0.0005	0.0020
10-JAN-83	0.00025	0.34	0.310	0.0005	0.0020
07-MAR-83	0.00210	6.90	0.960	0.0005	0.0020
16-MAY-83	0.00025	2.00	0.100	0.0005	0.0020
06-JUN-83	0.00025	0.26	0.210	0.0005	0.0020
27-JUN-83	0.00060	0.58	0.210	0.0005	0.0020
18-JUL-83	0.00050	0.48	0.070	0.0010	0.0020
08-AUG-83	0.00070	0.75	0.130	0.0005	0.0020
15-AUG-83					
12-SEP-83	0.00190			0.0005	0.0020
03-OCT-83	0.00210	0.32	0.140	0.0010	0.0020
16-OCT-83	0.00230	0.32	0.110	0.0020	0.0030
12-DEC-83					
30-JAN-84	0.00080	0.42	0.300	0.0005	0.0005
05-MAR-84	0.00110	4.70	0.920	0.0005	0.0005
04-JUN-84	0.00040	0.29	0.080	0.0005	0.0005
19-JUN-84	0.00040	0.37	0.060	0.0005	0.0005
25-JUN-84	0.00050	0.52	0.050	0.0005	0.0010
10-JUL-84	0.00040	0.31	0.030	0.0005	0.0010
23-JUL-84	0.00070	0.44	0.070	0.0060	0.0010
21-AUG-84	0.00050	0.26	0.110	0.0050	0.0010
28-AUG-84	0.00060	0.28	0.020	0.0080	0.0005

APPENDIX B 1984 CUMBERLAND MARSHES OPERATIONS REPORT
1984 WATER QUANTITY MONITORING RESULTS

WATER QUANTITY MONITORING PROGRAM

CUMBERLAND MARSHES PROJECT

1984 OPERATIONS

Prepared By:

Water Resources Branch

Inland Waters Directorate

Environment Canada

Regina, Saskatchewan
1985 05 08

WATER QUANTITY MONITORING

INTRODUCTION

This seventh annual report to the Prairie Provinces Water Board documents water management and surface water monitoring activities in the Ducks Unlimited (Canada) Cumberland Marshes Project for the calendar year 1984.

The location, monitoring points and structural details - natural and constructed channels, lakes, marshes and control works - are shown on the maps included with this report. The project area approximates a 1 300 km^2 rectangle bounded on the north by the Saskatchewan River Old Channel, on the east by the Manitoba-Saskatchewan boundary, on the south by Petabec Creek and the Birch River and on the west by the east boundaries of townships 55 and 56, range 6 west of the 2nd meridian. The area, a part of the Saskatchewan River delta, lies within a physiographic unit classified as the Cumberland Lake Lowland which forms part of the Manitoba Lowlands Region and is considered one of the outstanding wetland wildlife areas in North America.

Apart from the natural flow and storage regime, project water supplies may be augmented by regulated diversion from the Saskatchewan River Old Channel via the Dragline Channel to off-channel storage in Cut Beaver Lake. From Cut Beaver Lake, water may be routed to the various project lakes and marshes as required. Surplus water, riparian flows and supplies required for downstream use are delivered through and regulated by the Birch River Dam at the lower (east) end of the project and reach Manitoba via the Saskeram River.

Within the project, flows and water levels are regulated and adjusted by means of a complex system of natural and artificial channels, dykes and control structures. The project design is such that water levels within a number of management units can be regulated independently and within a time frame consistent with the objective of maximizing waterfowl and furbearer production by means of habitat improvement and maintenance.

The water quantity/quality monitoring program remained unchanged in 1984 and the network consisted of the following stations:

05KH011 Dragline Channel near Squaw Rapids
This station produces a twelve month record of flow into the project. A water quality sampling site is collocated here;

05KH014 Birch River Marsh near Cumberland House
This station produces a twelve month water level record. The record is in fact Birch River Dam headpond elevation and is used to compute regulated project releases to Manitoba via the Birch and Saskeram rivers;

05KH013 Birch River near Manitoba Boundary
As a hydrometric station, this is a map location only at which flows are computed using the Birch River Marsh record and a schedule of gate operations at Birch River Dam. A water quality sampling site is collocated here.

Operations During 1984

The water quantity monitoring program in the Ducks Unlimited Cumberland Marshes project continued with no change in 1984. Hydrometric stations were operated throughout the year on the Dragline Channel and Birch River Marsh. Daily discharges for Birch River near Manitoba Boundary were computed for the entire year with gate leakage estimated when stoplogs were in place. Hydrometric data are attached.

Good quality stage record was obtained at hydrometric station 05KH011 Dragline Channel near Squaw Rapids during the year. Thirty-one discharge measurements and two zero flow observations were made during the season by Water Survey of Canada and Ducks Unlimited personnel. The two zero flow observations made by Ducks Unlimited were not used in computing the discharge record as Water Survey of Canada staff made measurements at approximately the same gauge height within two days of the zero flow observations. Measurement quality was considered to be good for most measurements but fair to poor for the low flow measurements due to very low velocities. The stage-discharge relation and discharge record is considered to be poor to fair for this station due to operation of the control structure and the effect of changing water levels in the Saskatchewan River Old Channel.

The hydrometric station 05KH014 Birch River Marsh near Cumberland House was operated throughout the year by Ducks Unlimited with periodic visits by Water Survey of Canada personnel. Missing stage record occurred from January 9 to February 13 and March 6 to 23 due to pen carriage jamming. The quality of the stage record was considered to be good.

Daily discharges for the station 05KH013 Birch River near Manitoba Boundary were computed by Saskatchewan Water Corporation based on the elevation of the Birch River Marsh and the stoplog operation of the outlet structure. Gate leakage was estimated at 0.015 m^3/s during the year. An analysis of the flow meterings undertaken by Water Survey of Canada personnel in 1983 suggested that the accuracy of the record could be improved by using a bay width of 11 feet instead of 10 feet. However, computations for 1984 were based on the latter coefficient to ensure consistency with previous records. No check meterings were done in 1984 and, as a result, the discharge record for this station is considered to be poor.

The 1984 hydrometric records produce the following crude project water inventory:

Volume diverted from Saskatchewan River Old Channel to project (recorded)	20 900 dam^3
Volume released from project to Manitoba (computed)	39 200 dam^3
Net storage computed from Ducks Unlimited project area	69 dam^3
Unrecorded (or unknown) project usage including conveyance and evaporative losses, unrecorded or unknown storage, groundwater recharge	-18 369 dam^3
Apparent project diversion	-18 300 dam^3

Actual project usage may be higher as no adjustment has been made for local inflow or direct increase in lake storage due to precipitation.

The details of the project operation during 1984 are included in the attached operations report from Ducks Unlimited (Canada).

1984 Cumberland Marshes Operations Report

Dave Phillips
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Ducks Unlimited Canada
Cumberland House, Sask.
November 6, 1984

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1.0 Introduction

Since 1978, Ducks Unlimited Canada has carried out a water quantity/quality monitoring program at the Cumberland Marshes project in co-operation with the Water Survey of Canada and Environment Canada Water Quality Branch. The program seeks to compile annual surface water data to document flows entering and leaving the project as well as water quality trends attributable to project operations.

The present report summarizes 1984 operations at the project for both agencies. This combined approach began in 1982 to stream-line reporting procedures. It is hoped that this format continues to provide adequate documentation for interpretations of both water utilization and water quality results.

As in past years, Hydrometric Station #05KH014 was used to estimate discharges from the Cumberland project to Manitoba via the Cumberland Marshes Dam on the Birch River. Hier formula estimates of mean daily flows at the station have been calculated from the stage record and stop log elevations and appear in this report. The precision of these flow estimates has been improved in 1984 by utilizing an 11' log length constant for calculation purposes instead of the 10' value employed in past years. This revision was based upon comparitive flow meterings carried out below the dam by WSC in 1983.

Inflow diverted from the Saskatchewan River Old Channel was recorded by Hydrometric Station #05KH011 at the Dragline Channel with bi-monthly gauging of the station completed by Ducks Unlimited staff during periods when the inlet structure was in operation. The theoretical water balance calculated in this report indicates a total diversion of approximately 15,447 acre feet; verification of this estimate will be provided with publication of flows at the station by WSC.

Simultaneous water quality samples were collected at the Birch River and Dragline Channel sampling stations on 10 occasions during 1984. These samples completed the initial 5 year term of the Cumberland water quality program and all sampling equipment was returned upon request to the Water Quality Branch after the last collection on October 29, 1984. A detailed interpretation of past data from the program is underway and will culminate with a final suumary report in the spring of 1985.

2.0 General Operations

Fish survival in Cut Beaver Lake was protected over the winter of 1983/84 by maintaining a continuous inflow of 25 c.f.s. from the Saskatchewan River (Old Channel) via the Dragline Channel. The inlet control structure was opened on November 13, 1983 after sufficient ice cover had formed above the inlet to discourage beaver activity at the site. Past experience has shown that beavers quickly obstruct the inlet if winter inflow rates (>30 c.f.s.) are established before ice cover has developed.

The 25 c.f.s. inflow to Cut Beaver was maintained until April 27, 1984 when flows were increased to complete refilling of the storage reservoir. On the basis of bi-monthly flow meterings and the theoretical water balance calculated in this report, the total diversion from the Old Channel to Cut Beaver Lake between November 13, 1983 and July 4, 1984 is estimated to have been 15,447 ac.ft. When flows in the Old Channel dropped to near zero at the end of June and the Dragline inlet was closed (July 4), the reservoir elevation had reached 878.70' and provided enough storage capacity to meet operations demands through the 1984 season.

The winter operation of the Dragline inlet structure maintained adequate dissolved oxygen concentrations for over-winter fish survival in Cut Beaver and also accomplished a partial refill of the reservoir prior to spring break-up. In view of the very low flows which characterized the Old Channel during most of the 1984 open water season, this winter refill of Cut Beaver was later found to be a critical element of the operations schedule. Adequate storage could not have been diverted from the Old Channel during the spring run-off period (May/June).

Early snowfalls which accompanied the onset of freeze-up in November, 1983 insulated new ice cover and reduced the depth of ice penetration on local water bodies over the course of the winter. These thin ice conditions combined with unusually warm temperatures in late March to produce open water patches along shorelines and near control structures by the first week of April. A small number of dead Northern Pike were observed below the outlet controls on Cut Beaver Lake at this time leading a local resident to report that the reservoir had been winter-killed. Subsequent test net settings by S.P.&.R.R. staff on May 9 & 10 indicated that healthy populations of pike and Lake Whitefish were present in the lake and that no significant fish die-off had taken place.

By April 24, only 10% of the project area remained ice-covered which enabled operators to initiate the removal of sheet water from the exposed McGregor Lake

basin 16 days prior to the planned start-up date of May 10. Seepage from adjacent water bodies and snowmelt had raised the water level on this unit by about 2' over the course of the 1983/84 winter requiring early re-exposure to promote emergent plant germination during the 1984 growing season. The Cumberland Marshes Dam and McGregor Lake outlet controls were opened on April 24 to begin the operation at an average discharge rate of 150 c.f.s. (Table 1).

Preliminary estimates had indicated that 9,987 ac.ft. could be drained from McGregor Lake and Birch River Marsh Centre over a period of 27 days to complete the operation by early June. However, heavy snowfalls in mid-May coupled with regular rainfalls during June extended the operation's duration to June 28 when the target elevation of 864.45' had been reached on McGregor. This precipitation contributed an additional 4,652 ac.ft. to the total discharge from McGregor Lake and Birch River Marsh Centre over the course of the drawdown operation (Table 2).

Junction Lake and Beaton Lake outlet controls were opened on June 28 to begin the scheduled Junction Lake drawdown via the East Channel, Bewley/Beaton and Birch River Marsh Centre. Although the initial operations plan projected completion of this drawdown within 27 days at a discharge rate of 150 c.f.s. at the Cumberland Marshes Dam, beds of floating vegetation began to obstruct the Junction Lake outlet canal from the outset of the operation. Explosives were used to blast a new channel bypassing the obstructed outlet but discharge rates remained below 75 c.f.s. throughout the drawdown

By July 26, accellerating evaporation demands in the Carrot River Triangle complex led DU project operators in the Pas area to request increased discharge at the Cumberland Marshes Dam. To accomodate this request, supplementary flows were routed from Cut Beaver Lake into Bewley/Beaton via the West and East Channels between July 26 and August 10. As in past years, fine-mesh screening nets were installed above the outlets to Cut Beaver Lake to restrict the passage of fish out of the reservoir during the operating season. Although the net barrier is believed to be effective in preventing the downstream migration of larger fish, smaller fish may be able to pass through the 1¼" mesh of the screening instalation. Larger fish situated between the instalation site and the reservoir's outlets when the nets are initially emplaced may also migrate downstream when the outlets are opened.

By August 10, discharge from the Junction Lake drawdown had declined below 25 c.f.s. as the unit approached a water level of 874.44. Stage/storage curves had indicated that the minimum drawdown level for Junction was 873.0' but it was discovered that the outlet channel actualy terminates near the 874.5' basin contour. Although subsequent evaporation reduced the unit's water level to 874.09' by September 27, total discharge from Junction was only 5,097 ac.ft. (Table 2) compared with the initial estimate of 7,900 ac.ft. derived from storage curve data. This discharge combined with supplementary flows from Cut Beaver (954 ac.ft.) provided a total volume of 6,651 ac.ft. to Manitoba between June 28 and August 13.

Hot, dry weather coupled with peaking evapotranspirative water demands by local aquatic plant cover in July and August reduced local lake levels by approximately 0.35'. Retopping operations were initiated along the West Channel conveyance route on July 25 to compensate for these evaporation losses in Muskeg, Deep, Highbank and Egg Lakes (Table 2). The total volume removed from Cut Beaver to meet these operations is estimated to have equalled 1,442.0 ac.ft. between July 25 and August 27.

When the Junction Lake drawdown had tapered off to minimal rates of discharge in mid-August, Beaton outlet was closed to conserve the remaining flow out of Junction and begin restoring Bewley/Beaton Lakes to operating level. By August 27 it became evident that little additional discharge was available from Junction Lake and Egg Lake outlet was opened to restore operating levels in Big, Bewley/Beaton and North McGregor Lakes. This operation had been tentatively discussed by the Cumberland Marshes Management Committee at the May 23 meeting and was verbally approved by the Delta Fur Block immediately prior to opening Egg outlet. Between August 27 and September 14, Egg Lake was lowered by approximately 0.75' which contributed 3,550 ac.ft. to the three downstream units and restored their respective operating levels prior to freeze-up. All inlets to Big, Bewley/Beaton and North McGregor Lakes were left open at the end of the operating season to accomodate runoff from Junction Lake in the spring of 1985. It is hoped that this operation will provide adequate storage for discharge from Junction and permit early exposure of the Junction Lake basin for revegetation purposes.

The final major operation of the 1984 season involved the export of 11,259 ac.ft. to Manitoba from Cut Beaver Lake via the West Wapisew/Birch River conveyance route between August 13 and October 10. Based upon the stage record from the automatic recording station at the Cumberland Marshes Dam (Table 1) and stop leg elevations at the structure throughout the 1984 operating season (Table 3), the total volume discharged from Cumberland into the Birch River

equalled 34,138.2 ac.ft. On October 10, the Cumberland Marshes Dam was closed by installing all available stop logs at the site. It was hoped that the additional weight of stop logs above the water line would aid in sealing leaks and reduce the duration of open water below the structure.

The damsite was visited on October 29 to start the propane heater in the recording gauge shelter and collect the last water quality sample of the current schedule. At this time it was evident that the additional logs were effective in reducing leakage through the dam and ice cover had already formed on the stilling pool below the structure. It is hoped that fish populations in the Birch River below the dam will disperse downstream in the absence of leakage and reduce the probability of winter-kill at the site.

The fish screening nets were removed from Cut Beaver Lake on October 22 after discharge from the reservoir had ended. The operation is believed to have produced equivalent results to past years and fish populations remain high in the lake. Recreational anglers utilized Cut Beaver extensively throughout the open water period and excellent success was reported for large Northern Pike. As populations continue to respond to DU's fisheries management programs the lake's commercial and recreational potential is expected to improve. A quota for 5,000 lbs. is presently open for commercial fishermen at Cut Beaver and moderate interest has been expressed by local residents. As in past years, winter inflow will be maintained via the Dragline Channel inlet to protect over-wintering fish stocks in the lake during the 1984/85 winter season.

3.0 Flow sources on water quality sampling dates

(a) Dragline Channel: Inflow was moderate (25 c.f.s.) during the period January 1 - April 27 when 2 samples were taken (January 30 & March 5). Higher rates of inflow (100 c.f.s.) prevailed between April 27 and June 30 when 3 samples were collected (June 4, 19 & 25) and after July 4 when the inlet structure was closed, no detectable inflow was present at the site. The remaining 5 samples (July 10, 23, August 20, 28 and October 29) were collected under these zero flow conditions.

(b) Birch River below Cumberland Marshes Dam:

January 30 - No discharge except leakage from Birch River Marsh Centre (trace)
March 5 - As above
June 4 - McGregor Lake drawdown (includes Birch River Marsh Centre)
June 19 - McGregor Lake drawdown (includes Birch River Marsh Centre)
July 10 - Junction Lake drawdown (includes Bewley/Beaton & Birch R. Marsh Cen
July 23 - As above

August 20 - Cut Beaver Lake via West Wapisew and Birch River Marsh Centre

August 28 - As above

October 29 - Trace leakage from Birch River Marsh Centre (No discharge)

4.0 Theoretical Water Balance:

INFLOW = STORAGE + DISCHARGE + NET EVAPORATION REPLACEMENT

1) STORAGE =	Internal storage from operations (Table 1)	= 6,144.0
	(-)Total drawdown waters used internally (Table 1)	= 4,285.0
		= 1,856.0
2) DISCHARGE =	Total releases to Manitoba (Table 1)	= 34,138.2
	(-)Internal releases to Manitoba (Table 1)	= 21,924.6
		= 12,213.6

3) NET EVAPORATION REPLACEMENT

= Evaporation on units retopped (Table 1)	= 2,913.0
(+)Evaporation on Cut Beaver Lake *(Note #1)	= 3,775.0
(-)Runoff to Cut Beaver *(Note #2)	= 5,309.5
	= 1,378.5

INFLOW = 1,856.0 + 12,213.6 + 1,378.5 = 15,446.5

* Note 1 - Evaporation on Cut Beaver estimated to be 431.0 ac.ft. between July 4 (Dragline closed) and July 25 (outlets opened); plus estimated 3,344.0 ac.ft. between July 25 and Oct. 1 (outlets closed; Table 1); total over the period (July 4-Oct. 1) = 3,775.0

* Note 2 - Runoff to Cut Beaver (Jan.1 - July 4) estimated to be 0.41' based upon documented surplus volumes in McGregor Lake drawdown over this period; 0.41' x 12,950 ac. (Cut Beaver area)= 5,309.5

5.0 Net Change in Internal Storage

Table 4 presents final lake elevations at the end of the 1984 operating season (September 27). Based upon water levels on September 27, 1983 and September 27, 1984, the net change in internal storage between 1983 and 1984 is estimated to be + 56 ac.ft.

Table 1. Estimated mean daily discharges from the Cumberland Marshes project into the Birch River via the Cumberland Marshes Dam during 1984.

Date	Discharge (c.f.s.)	Volume (ac.ft.)	Operations contributing to flow
April 24			-Opened Cumberland Marshes Dam & McGregor outlet
25	190.7	381.4	
26	176.1	352.2	
27	164.7	329.4	
28	172.3	344.6	
29	165.5	331.0	
30	155.8	311.6	
		2,050.2	
May 1	148.0	296.0	
2	135.9	271.8	-Pulled 1 log from bay #5
3	155.8	311.6	
4	145.9	291.8	
5	139.4	278.8	
6	135.9	271.8	
7	127.2	254.4	
8	120.5	241.0	
9	110.7	221.4	
10	92.9	185.8	
11	107.6	215.2	
12	100.1	200.2	
13	109.5	219.0	-Pulled 1 log from bay #5; serviced gauge
14	122.0	244.0	
15	107.0	214.0	
16	105.8	211.6	
17	109.8	219.6	
18	102.9	205.8	
19	108.7	217.4	
20	97.9	195.8	
21	112.8	225.6	
22	118.2	236.4	
23	121.3	242.6	
24	109.2	218.4	
25	108.7	217.4	
26	103.5	207.0	
27	98.5	197.0	
28	93.2	186.4	
29	83.1	166.2	
30	77.9	155.8	
31	82.6	165.2	
		6,985.0	
June 1	78.4	156.8	
2	68.2	136.4	
3	66.1	132.2	
4 *	70.1	140.2	-Pulled 2 logs from bay #3, 1 from bay #4 and 2 from #6; cleared floating debris
5	221.2	442.4	
6	158.0	316.0	
7	136.1	272.2	

* Denotes water quality sample collection dates

Table 1. (continued)

Date	Discharge (c.f.s.)	Volume (ac.ft.)	Operations contributing to flow
June 8	139.7	279.4	
9	162.4	324.8	
10	156.5	313.0	
11	144.1	288.2	
12	120.9	241.8	
13	119.5	239.0	
14	104.4	208.8	-Pulled 1 log each on bays #3 &#4; serviced gauge
15	144.5	289.0	
16	136.9	273.8	
17	130.9	261.8	
18	131.5	263.0	
19*	128.2	256.4	Pulled 1 log each on bays #5 &#6
20	135.6	271.2	
21	178.5	357.0	
22	170.0	240.0	
23	167.7	335.4	
24	159.5	319.0	
25*	146.2	292.4	
26	141.2	282.4	
27	129.9	259.8	
28	120.1	240.2	-Closed McGregor outlet; opened Beaton outlet
29	139.7	279.4	
30	145.5	291.0	
		8,003.0	
July 1	145.5	291.0	
2	141.8	283.6	
3	132.7	265.4	-Installed 1 log each in bays #3,4,5&6; serviced gauge
4	66.4	132.8	
5	78.8	157.6	
6	87.3	174.6	
7	91.0	182.0	
8	96.6	193.2	
9	97.4	194.8	
10*	96.0	192.0	Installed 1 log each in bays #3,4,5&6
11	30.2	60.4	
12	40.1	80.2	
13	41.9	83.8	
14	60.8	121.6	
15	67.5	135.0	
16	70.3	140.6	
17	69.8	139.6	
18	70.3	140.6	
19	70.3	140.6	
20	69.1	138.2	
21	69.1	138.2	
22	69.1	138.2	
23*	67.5	135.0	
24	65.8	131.6	
25	63.6	127.2	
26	63.6	127.2	
27	60.5	121.0	

Table 1. (continued)

Date		Discharge (c.f.s)	Volume (ac.ft.)	Operations contributing to flow
July	28	60.3	120.6	
	29	60.3	120.6	
	30	56.5	113.0	-Cleared floating debris; serviced gauge
	31	60.8	121.6	
			4,641.8	
August	1	60.5	121.0	
	2	55.7	111.4	
	3	54.5	109.0	
	4	54.0	108.0	
	5	51.9	103.8	
	6	51.5	103.0	
	7	49.9	99.8	
	8	48.9	97.8	
	9	45.0	90.0	
	10	43.9	87.8	-Closed Beaton outlet
	11	34.7	69.4	
	12	27.0	54.0	
	13	21.9	43.8	-Opened Cut Beaver/Wapisew and Wapisew outlet
	14	18.6	37.2	
	15	15.1	30.2	
	16	19.3	38.6	
	17	23.4	46.8	
	18	25.8	51.6	
	19	27.0	54.0	
	20	41.1	82.2	
	21*	36.9	73.8	-Serviced gauge; cleared floating debris
	22	40.7	81.4	
	23	39.3	78.6	
	24	48.3	96.6	
	25	54.0	108.0	
	26	63.6	127.2	
	27	64.8	129.6	-Increased flow at Cut Beaver/Wapisew
	28*	74.9	149.8	
	29	81.9	163.8	
	30	104.9	209.8	
	31	110.1	220.2	
			2,978.2	
September	1	112.2	224.4	
	2	114.8	229.6	
	3	120.1	240.2	
	4	121.6	243.2	-Cleared floating debris
	5	125.7	251.4	
	6	125.7	251.4	
	7	127.8	255.6	
	8	136.1	272.2	
	9	136.1	272.2	
	10	136.1	272.2	-Blasted beaver dams on Birch River
	11	136.1	272.2	
	12	136.1	272.2	

Table 1. (continued)

Date	Discharge (c.f.s.)	Volume (ac.ft.)	Operations contributing to flow
September 13	136.1	272.2	-cleared floating debris
14	134.0	268.0	
15	140.4	280.8	
16	140.4	280.8	
17	142.6	285.2	
18	142.6	285.2	
19	141.1	282.2	
20	138.1	276.2	
21	127.0	254.0	
22	127.0	254.0	
23	140.4	280.8	
24	141.1	282.2	
25	138.1	276.2	
26	150.6	301.2	-Inspection visit by WSC; serviced gauge &
27	147.6	295.2	cleared floating debris
28	146.2	292.4	
29	141.8	283.6	
30	141.1	282.2	
		8,089.2	
October 1	141.1	282.2	-Closed Cut Beaver/Wapisew and Wapisew outlet
2	128.3	256.6	
3	101.8	203.6	
4	73.7	147.4	
5	59.3	118.6	
6	53.4	106.8	
7	41.6	83.2	
8	35.6	71.2	
9	32.4	64.8	
10	28.2	56.4	-Closed Cumberland Marshes dam for year end
		1,390.8	

Summary of 1984 Discharges:

April = 2,050.2 ac.ft.
May = 6,985.0 ac.ft.
June = 8,003.0 ac.ft.
July = 4,641.8 ac.ft.
August = 2,978.2 ac.ft.
September = 8,089.2 ac.ft.
October = 1,390.8 ac.ft.
TOTAL = 34,138.2 ac.ft.

Table 2. Water budget for 1984 operations at the Cumberland Marshes project.

Lake	BEGIN Existing Elevation (feet)	END Target Elevation (feet)	Estimated Net Runoff or Evaporation (ac.ft.)	Estimated Inflow (ac.ft.)	Change in Volume (ac.ft.)	Surplus Volume (ac.ft)	Released To	Period From	Period To	Duration (days)	Discharge Rate (cfs)
CUMBERLAND DRAWDOWNS:											
1. McGregor Lake	866.43	864.45	+3,876.3	0	8,354.0	12,230.3	B.R. Marsh	April 24	June 28	64	96.0
Birch River Marsh	866.43	864.16	+775.3	12,230.8	3,222.0	16,227.6	Birch Lake	April 24	June 28	64	127.0
2. Junction Lake	876.17	874.44	-1,273.0	0	6,370.0	5,097.0	Bewley/B.	June 28	Aug. 10	42	61.0
Cut Beaver Lake	* Accounted	in #4.		0	954.2	954.2	Bewley/B.	July 26	Aug. 10	14	34.0
Bewley/Beaton	868.12	867.45	-446.0	6,051.2	2,100.0	7,705.2	B.R. Marsh	June 28	Aug. 10	42	92.0
Birch River Marsh	864.16	864.90	-319.0	7,705.2	-735.0	16,651.?	Birch Lake	June 28	Aug. 13	45	73.0
3. Cut Beaver Lake	* Accounted	in #4.		0	13,560.0	13,560.0	W. Wapisew	Aug. 13	Oct. 1	48	141.0
West Wapisew Lake	874.52	875.37	-238.0	13,560.0	-1,870.0	11,452.0	B.R. Marsh	Aug. 13	Oct. 1	48	119.0
Birch River Marsh	864.90	864.95	-127.0	11,452.0	-66.0	11,259.4	Birch Lake	Aug. 13	Oct. 10	58	97.0
4. Cut Beaver Lake	878.70	877.45	-3,343.8	0	19,300.0	1,442.0	W. Channel	July 25		32	23.0
Muskeg Lake	876.84	877.03	-77.0	163.0	-86.0	HELD	HELD	July 26	Aug. 27	31	3.0
Deep Lake	876.03	876.28	-108.0	483.0	-375.0	HELD	HELD	July 26	Aug. 9	13	19.0
Highbank Lake	874.87	874.80	-654.0	348.0	45.0	HELD	HELD	July 26	Aug. 27	32	5.0
Egg Lake	872.58	872.50	-944.0	448.0	496.0	HELD	HELD	Aug. 1	Aug. 27	26	9.0

AA (April 24-October 10, 1984) = 34,138.2 ac.ft.

12.

Table 2 (continued)

Lake	BEGIN Existing Elevation (feet)	END Target Elevation (feet)	Estimated Net Runoff or Evaporation (ac.ft.)	Estimated Inflow (ac.ft.)	Change in Volume (ac.ft.)	Surplus Volume (ac.ft)	Released To	Period From	Period To	Duration (days)	Discharge Rate (cfs)
5. Egg Lake	872.50	871.78	-62.0	0	3,612.0	3,550.0	Big Lake	Aug. 27	Sept. 14	17	104.0
Big lake	868.06	868.12	-24.0	3,550.0	-136.0	3,390.0	Bewley/B.	Aug. 27	Sept. 27	30	57.0
Bewley/ Beaton	867.57	868.08	-30.0	3,390 0	-1,616.0	1,744.0	N. McGregor	Aug. 27	Sept. 27	30	29.0
North McGregor	876.48	867.93	-46.0	1,744.0	-1,698.0	0	HELD	Aug. 27	Sept. 27	30	0

Table 3. Stop log elevations at the Cumberland Marshes Dam during 1984

Date	STOP LOG ELEVATIONS* NORTH Bay 1	Bay 2	Bay 3	Bay 4	Bay 5	Bay 6	Bay 7	SOUTH Bay 8
November 24, 1983	3.604	3.842	3.590	3.614	3.612	3.625	3.629	3.589
April 24, 1984	3.604	3.842	3.172	3.018	3.224	3.218	3.629	3.589
May 2, 1984	3.604	3.842	3.172	3.018	3.021	3.218	3.629	3.589
May 13, 1984	3.604	3.842	3.172	3.018	2.818	3.218	3.629	3.589
June 4, 1984	3.604	3.842	2.765	2.815	2.818	2.811	3.269	3.589
June 14, 1984	3.604	3.842	2.562	2.612	2.818	2.811	3.629	3.589
June 19, 1984	3.604	3.842	2.562	2.612	2.615	2.608	3.629	3.589
July 3, 1984	3.604	3.842	2.765	2.815	2.818	2.811	3.629	3.589
July 10, 1984	3.604	3.842	2.968	3.018	3.021	3.014	3.629	3.589
October 10, 1984	3.827	4.016	3.809	3.818	3.799	3.793	3.775	3.735

Table 4. Lake elevations at the end of operations in the Cumberland Marshes project during 1983 and 1984

Lake	ELEVATION (feet) Sept.27/83	Sept.27/84	VARIATION (1983 to 1984) Elevation (ft.)	Volume (ac.ft)
Bewley/Beaton	867.8	868.1	+ 0.3	940
Big	867.9	868.1	+ 0.2	440
Birch River Marsh Centre	864.5	865.5	+ 1.0	1,350
Birch River Marsh North	865.8	865.7	- 0.1	- 300
Birch River Marsh South	865.3	865.5	+ 0.2	+ 256
Bloodsucker	875.0	875.1	+ 0.1	+ 440
Bog	866.9	867.2	+ 0.3	+ 780
Cut Beaver	877.4	877.5	+ 0.1	+ 1,000
Deep	875.9	876.4	+ 0.5	+ 740
Egg	872.8	871.8	- 1.0	- 5,380
Highbank	874.8	874.8	same	0
Junction Flats	874.6	874.8	+ 0.2	+ 28
Junction	876.1	874.1	- 2.0	- 6,700
McGregor	865.0	865.0	same	0
North McGregor	867.3	867.9	+ 0.6	+ 2,160
Muskeg	877.0	877.1	+ 0.1	+ 62
Rat/Petabecs	867.4	867.4	same	0
Waterhen	874.2	874.2	same	0
East Wapisew	873.5	874.1	+ 0.6	+ 2,260
West Wapisew	874.5	875.4	+ 0.9	+ 1,980

Net Change in internal storage = + 56 ac.ft.

APPENDIX C HYDROGRAPHS FOR THE DRAGLINE CHANNEL AND BIRCH RIVER MONITORING LOCATIONS 1979-1983

BIRCH RIVER NEAR MANITOBA BOUNDARY

1979 - 84

BIRCH RIVER NEAR MANITOBA BOUNDARY — STATION NO. 05KH013

DAILY DISCHARGE IN CUBIC METRES PER SECOND FOR 1984

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	0.015 B	0.015 B	0.015 B	0.015 B	4.03	1.70	3.48	1.55	2.85	3.70	0.015 B	0.015 B	1
2	0.015 B	0.015 B	0.015 B	0.015 B	4.17	1.67	3.43	1.53	2.89	3.38	0.015 B	0.015 B	2
3	0.015 B	0.015 B	0.015 B	0.015 B	4.20	1.80	2.09	1.47	2.99	2.65	0.015 B	0.015 B	3
4	0.015 B	0.015 B	0.015 B	0.015 B	3.99	3.39	1.62	1.45	3.04	1.99	0.015 B	0.015 B	4
5	0.015 B	0.015 B	0.015 B	0.015 B	3.82	3.97	2.00	1.42	3.06	1.61	0.015 B	0.015 B	5
6	0.015 B	0.015 B	0.015 B	0.015 B	3.70	3.48	2.25	1.41	3.01	1.39	0.015 B	0.015 B	6
7	0.015 B	0.015 B	0.015 B	0.015 B	3.53	3.76	2.41	1.41	3.45	1.15	0.015 B	0.015 B	7
8	0.015 B	0.015 B	0.015 B	0.015 B	3.34	4.18	2.52	1.35	3.43	0.989	0.015 B	0.015 B	8
9	0.015 B	0.015 B	0.015 B	0.015 B	2.92	3.93	2.58	1.30	3.50	0.896	0.015 B	0.015 B	9
10	0.015 B	0.015 B	0.015 B	0.015 B	2.70	3.48	1.62	1.21	3.47	0.160	0.015 B	0.015 B	10
11	0.015 B	0.015 B	0.015 B	0.015 B	3.03	2.97	0.817	1.03	3.41	0.015 E	0.015 B	0.015 B	11
12	0.015 B	0.015 B	0.015 B	0.015 B	2.83	3.04	1.16	0.806	3.41	0.015 E	0.015 B	0.015 B	12
13	0.015 B	0.015 B	0.015 B	0.015 B	3.24	2.97	1.34	0.637	3.47	0.015 E	0.015 B	0.015 B	13
14	0.015 B	0.015 B	0.015 B	0.015 B	3.18	3.50	1.62	0.539	3.48	0.015 E	0.015 B	0.015 B	14
15	0.015 B	0.015 B	0.015 B	0.015 B	2.83	3.61	1.82	0.529	3.59	0.015 E	0.015 B	0.015 B	15
16	0.015 B	0.015 B	0.015 B	0.015 E	2.80	3.38	1.88	0.617	3.70	0.015 E	0.015 B	0.015 B	16
17	0.015 B	0.015 B	0.015 B	0.015 E	2.70	3.26	1.90	0.699	3.80	0.015 E	0.015 B	0.015 B	17
18	0.015 B	0.015 B	0.015 B	0.015 E	2.70	3.23	1.93	0.763	3.80	0.015 E	0.015 B	0.015 B	18
19	0.015 B	0.015 B	0.015 B	0.015 E	2.86	3.55	1.94	0.851	3.78	0.015 E	0.015 B	0.015 B	19
20	0.015 B	0.015 B	0.015 B	0.015 E	2.64	3.47	1.90	1.20	3.69	0.015 E	0.015 B	0.015 B	20
21	0.015 B	0.015 B	0.015 B	0.015 E	2.95	4.16	1.94	1.16	3.47	0.015 E	0.015 B	0.015 B	21
22	0.015 B	0.015 B	0.015 B	0.015 E	3.07	4.27	1.97	1.22	3.58	0.015 E	0.015 B	0.015 B	22
23	0.015 B	0.015 B	0.015 B	0.015	3.07	4.24	1.93	1.25	3.85	0.015 E	0.015 B	0.015 B	23
24	0.015 B	0.015 B	0.015 B	2.78	2.90	3.93	1.88	1.45	3.85	0.015 E	0.015 B	0.015 B	24
25	0.015 B	0.015 B	0.015 B	5.05	2.87	3.59	1.85	1.67	3.87	0.015 E	0.015 B	0.015 B	25
26	0.015 B	0.015 B	0.015 B	4.78	2.71	3.45	1.82	1.90	3.89	0.015 E	0.015 B	0.015 B	26
27	0.015 B	0.015 B	0.015 B	4.47	2.52	3.06	1.81	1.96	3.87	0.015 E	0.015 B	0.015 B	27
28	0.015 B	0.015 B	0.015 B	4.55	2.29	2.82	1.74	2.22	3.84	0.015 E	0.015 B	0.015 B	28
29	0.015 B	0.015 B	0.015 B	4.53	2.12	3.34	1.69	2.49	3.78	0.015 E	0.015 B	0.015 B	29
30	0.015 B		0.015 B	4.22	2.09	3.50	1.67	2.68	3.72	0.015 E	0.015 B	0.015 B	30
31	0.015 B		0.015 B		2.01		1.62	2.75		0.015 E		0.015 B	31
TOTAL	0.465	0.435	0.465	30.725	93.81	100.70	60.227	42.521	105.54	18.230	0.450	0.465	TOTAL
MEAN	0.015	0.015	0.015	1.02	3.03	3.36	1.94	1.37	3.52	0.588	0.015	0.015	MEAN
DAM3	40.2	37.6	40.2	2650	8110	8700	5200	3670	9120	1580	38.9	40.2	DAM3
MAX	0.015	0.015	0.015	5.05	4.20	4.27	3.48	2.75	3.89	3.70	0.015	0.015	MAX
MIN	0.015	0.015	0.015	0.015	2.01	1.67	0.817	0.529	2.85	0.015	0.015	0.015	MIN

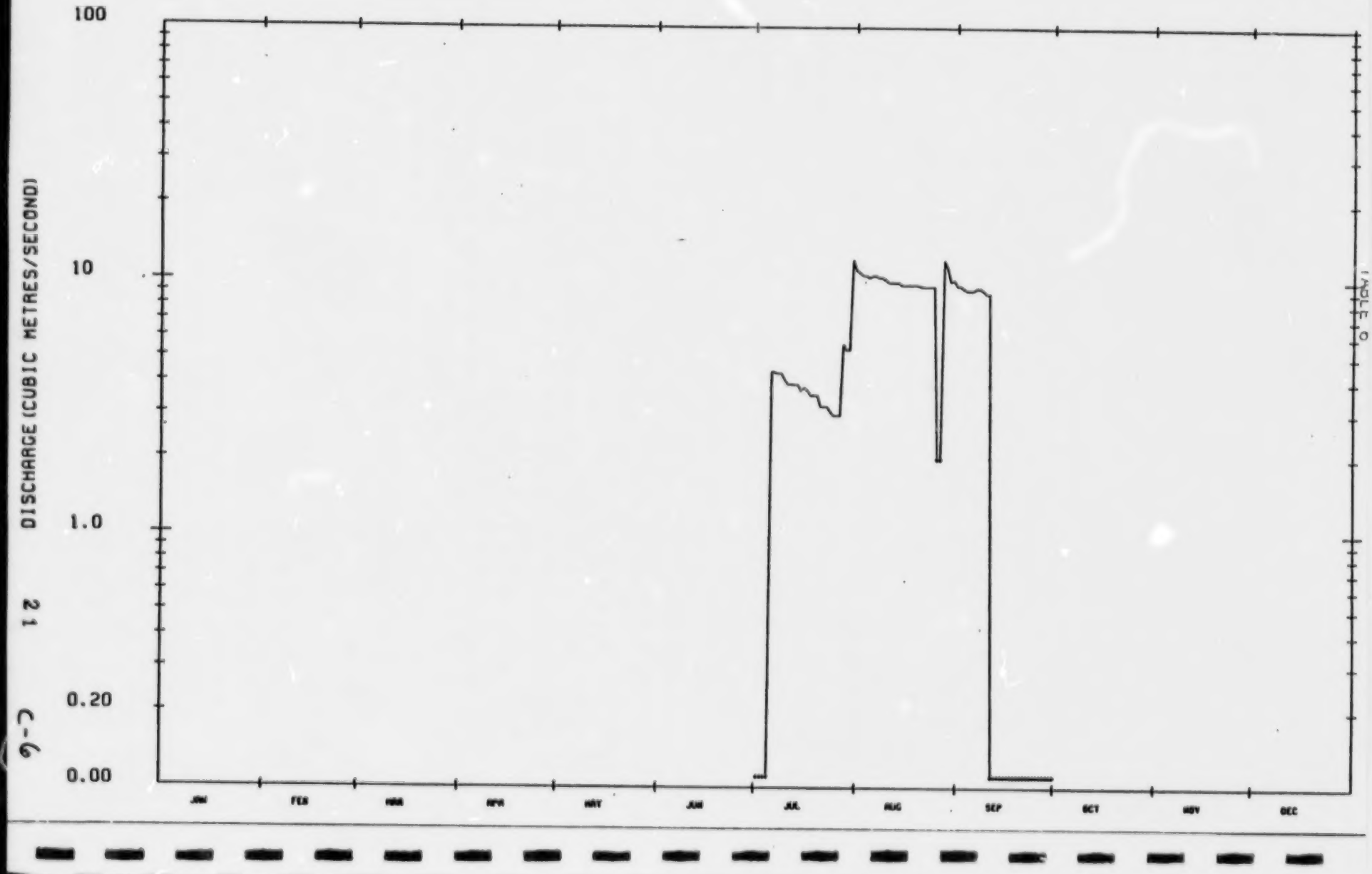
SUMMARY FOR THE MONTHS JAN TO DEC
MEAN DISCHARGE, 1.24 M3/S
TOTAL DISCHARGE, 39200 DAM3
MAXIMUM DAILY DISCHARGE, 5.05 M3/S ON APR 25
MINIMUM DAILY DISCHARGE,0.015 M3/S ON JAN 1

B-ICE CONDITIONS
E-ESTIMATED

5-2

WATER SURVEY OF CANADA
MAY 12 1980
REGINA, SASK

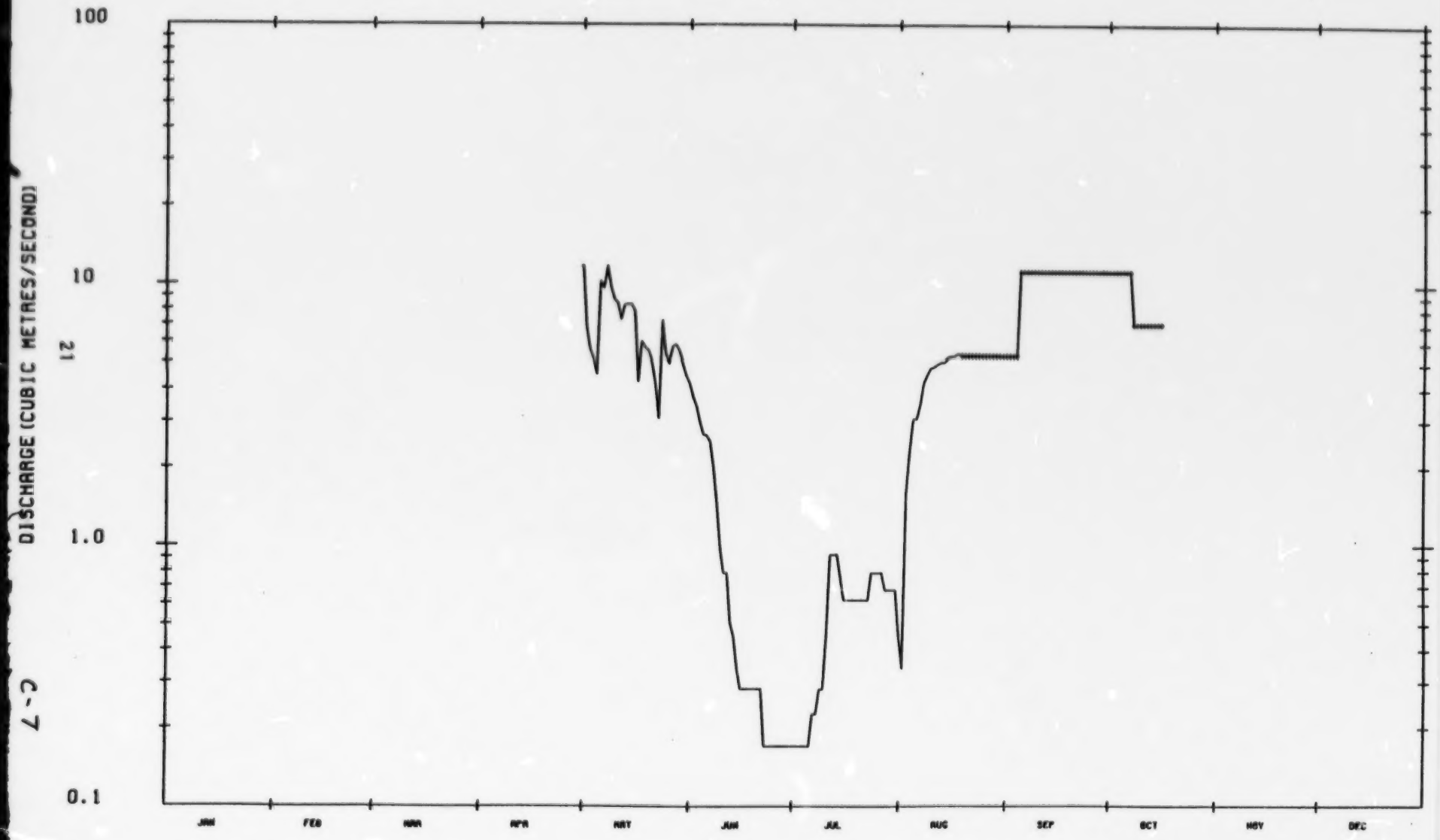
BIRCH RIVER NEAR MANITOBA BDY. SK
05KH013
1978



C-6 12

WATER SURVEY of CANADA
MAR 02 1981
REGINA, SASK

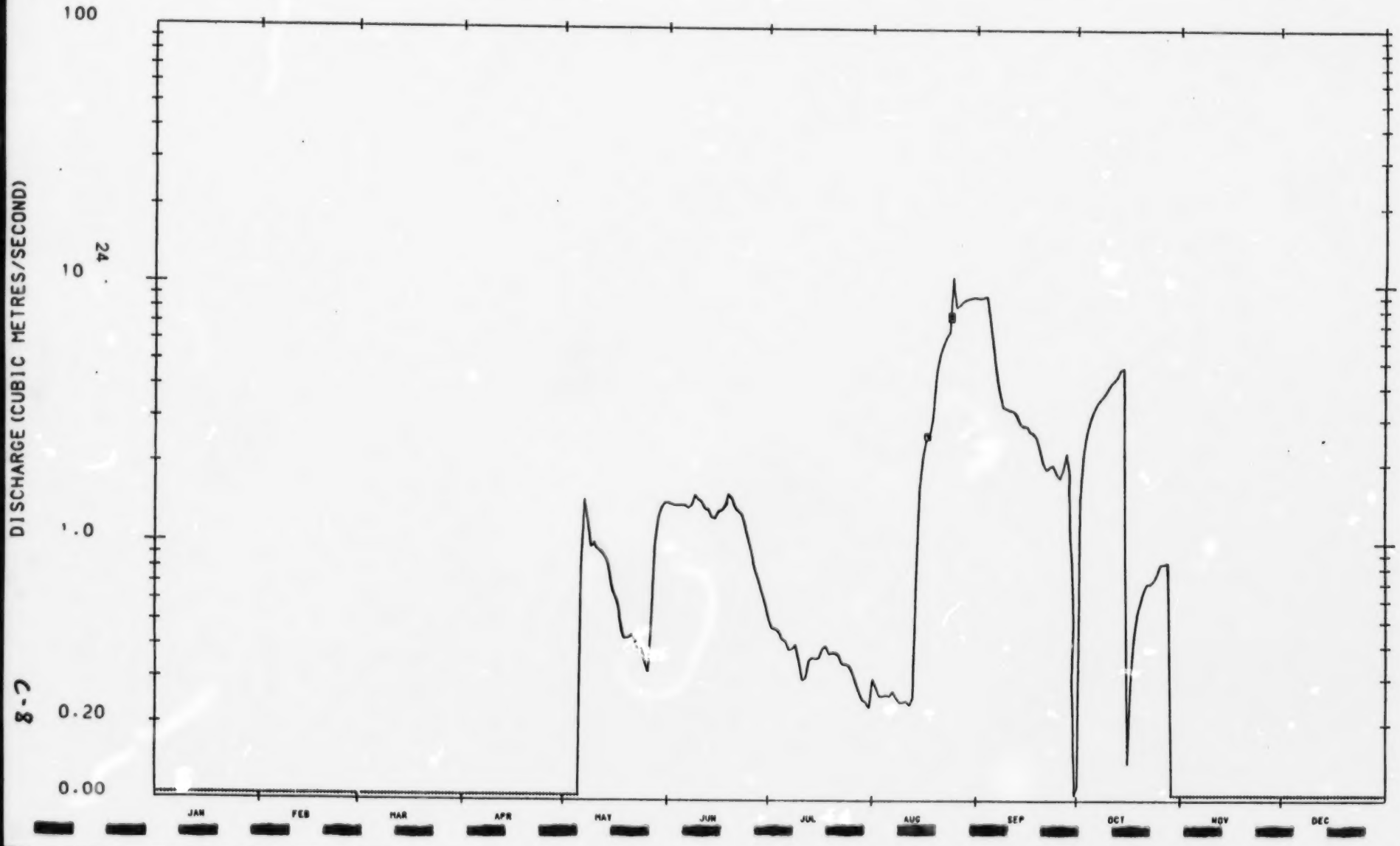
BIRCH RIVER NEAR THE MANITOBA BOUNDARY
08MH013
1980



C-7

WATER SURVEY OF CANADA
MAR 02 1981
REGINA, SASK

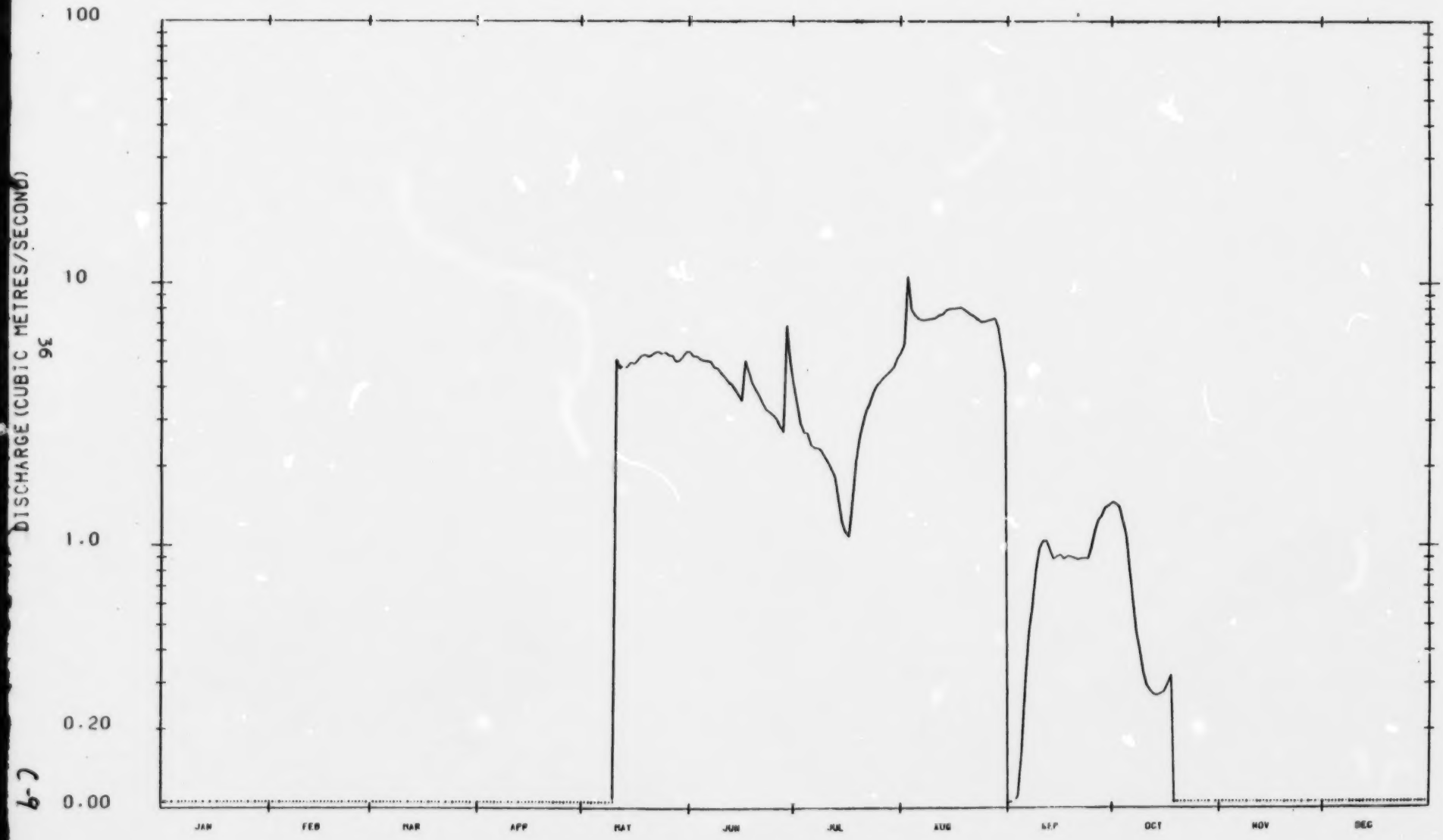
BIRCH RIVER NEAR MANITOBA BOUNDARY
05KH013
1981



8-2

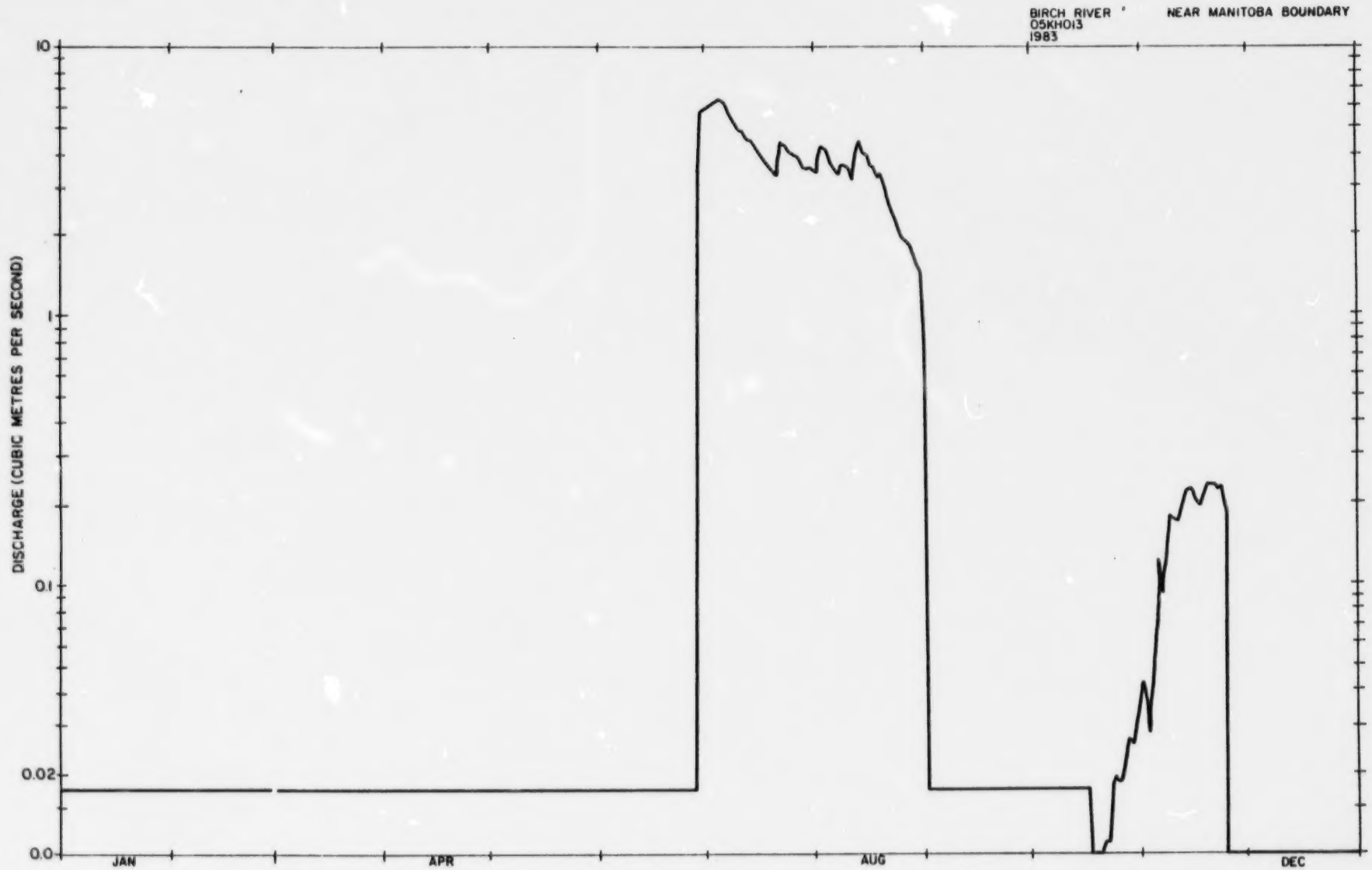
WATER SURVEY OF CANADA
APR 27 1983
REGINA, SASK

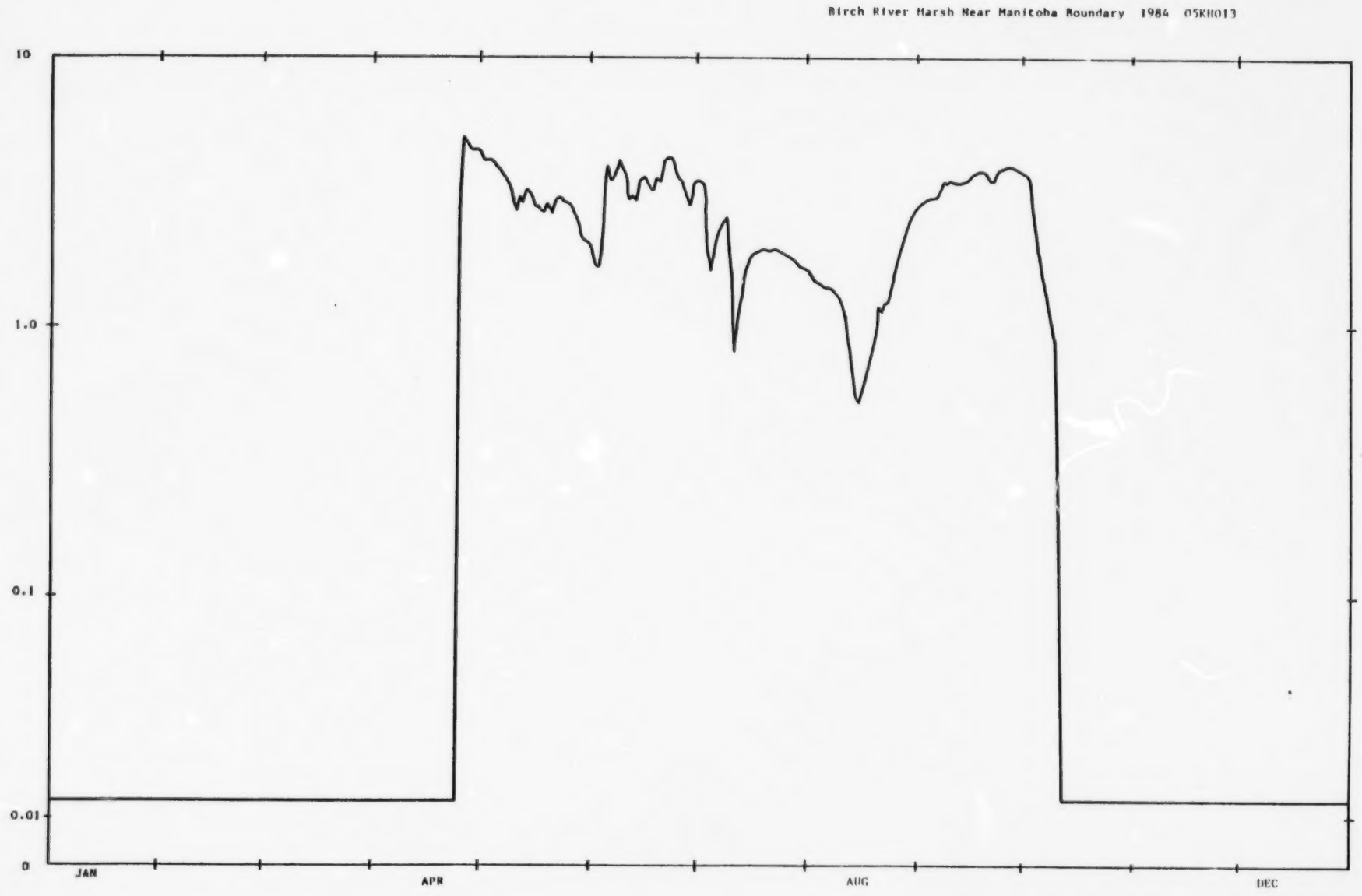
BIRCH RIVER NEAR MANITOBA BOUNDARY
05AN013
1982



36

6-2


BIRCH RIVER
05KH013
1983
NEAR MANITOBA BOUNDARY
DISCHARGE (CUBIC METRES PER SECOND)
10
1
0.1
0.02
0.0
JAN
APR
AUG
DEC


Birch River Marsh Near Manitoba Boundary 1984 05KH013
10
1.0
0.1
0.01
0
JAN
APR
AUG
DEC

C-11

DRAGLINE CHANNEL NEAR SQUAW RAPIDS

1979 - 84

WATER SURVEY OF CANADA
MAY 1 1985 PAGE 9
REGINA, SASK.

DRAGLINE CHANNEL NEAR SQUAW RAPIDS

STATION NO. 05KH011

(PRELIMINARY) DAILY DISCHARGE IN CUBIC METRES PER SECOND FOR 1984

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	0.523 B	0.650 B	0.704 B	0.616 B	1.54	1.21	1.66	0.386	0.375	0.430	0.674 B	0.672 B	1
2	0.503 B	0.574 B	0.573 B	0.641 B	1.60	0.980	0.629	0.278	0.289	0.481	0.630 B	0.700 B	2
3	0.488 B	0.640 B	0.487 B	0.664 B	1.55	0.777	0.367	0.302	0.500	0.483	0.459 B	0.715 B	3
4	0.581 B	0.634 B	0.456 B	0.662 B	1.44	0.721	1.07	0.276	0.514	0.505	0.608 B	0.868 B	4
5	0.626 B	0.957 B	0.542 B	0.655 B	1.55	0.859	0.122	0.162	0.556	0.668	0.808 B	0.814 B	5
6	0.603 B	0.751 B	0.548 B	0.662 B	1.34	0.718	0.463	0.111	0.623	0.733	0.689 B	0.797 B	6
7	0.600 B	0.674 B	0.674 B	0.662 B	1.05	0.688	0.219	0.112	0.686	0.708	0.669 B	0.732 B	7
8	0.715 B	0.625 B	0.613 B	0.617 B	1.57	0.638	0.264	0.189	0.714	0.648	0.646 B	0.407 B	8
9	0.645 B	0.612 B	0.691 B	0.569 B	1.82	0.556	0.246	0.237	0.785	0.719	0.629 B	0.386 B	9
10	0.770 B	0.595 B	0.694 B	0.573 B	1.12	0.452	0.203	0.323	0.714	0.756	0.646 B	0.408 B	10
11	0.761 B	0.558 B	0.735 B	0.534 B	0.945	0.391	0.209	0.399	0.690	0.779	0.560 B	0.457 B	11
12	0.719 B	0.521 B	0.702 B	0.570 B	1.10	0.339	0.189	0.400	0.796	0.697	0.534 B	0.640 B	12
13	0.710 B	0.540 B	0.703 B	0.876 B	0.688	0.473	0.279	0.382	0.816	0.732	0.566 B	0.684 B	13
14	0.738 B	0.636 B	0.575 B	1.11 B	0.957	0.320	0.201	0.071	0.813	0.686	0.508 B	0.737 B	14
15	0.756 B	0.568 B	0.725 B	1.15 B	1.51	0.325	0.162	0.078	0.734	0.715	0.574 B	0.758 B	15
16	0.755 B	0.506 B	0.720 B	1.14 B	1.43	0.496	0.176	0.154	0.610	0.696	0.622 B	0.661 B	16
17	0.778 B	0.492 B	0.697 B	1.06 B	1.13	0.517	0.235	0.207	0.579	0.632	0.725 B	0.679 B	17
18	0.772 B	0.529 B	0.597 B	1.01 B	1.39	0.353	0.199 A	0.274	0.683	0.648	0.667 B	0.777 B	18
19	0.705 B	0.591 B	0.510 B	0.843	0.538	0.352	0.486	0.236	0.438	0.668	0.661 B	0.861 B	19
20	0.737 B	0.539 B	0.462 B	0.678	1.22	1.43	0.468	0.182	0.255	0.668	0.584 B	0.805 B	20
21	0.722 B	0.636 B	0.588 B	0.472	1.17	1.70	0.477	0.183	0.138	0.624	0.494 B	0.889 B	21
22	0.652 B	0.590 B	0.854 B	0.411	0.932	1.85	0.414	0.164	0.092	0.577	0.563 B	0.874 B	22
23	0.618 B	0.523 B	0.760 B	0.400	1.05	1.78	0.348	0.202	0.045	0.518	0.533 B	0.949 B	23
24	0.643 B	0.608 B	0.690 B	0.458	0.779	1.43	0.546	0.363	0.036	0.459	0.384 B	0.951 B	24
25	0.714 B	0.548 B	0.637 B	0.441	0.974	0.592	0.604	0.360	0.018	0.490	0.361 B	0.812 B	25
26	0.608 B	0.609 B	0.710 B	0.418	1.08	1.91	0.606	0.375	0.015	0.517	0.408 B	0.508 B	26
27	0.648 B	0.627 B	0.940 B	1.13	0.981	1.90	0.539	0.380	0.100	0.552	0.642 B	0.173 B	27
28	0.632 B	0.593 B	0.770 B	1.95	0.973	1.85	0.473	0.455	0.307	0.555	0.671 B	0.087 B	28
29	0.608 B	0.624 B	0.719 B	1.25	1.18	2.10	0.518	0.507	0.234	0.670 B	0.670 B	0.448 B	29
30	0.580 B		0.657 B	1.19	1.19	1.97	0.544	0.312	0.334	0.965 B	0.666 B	0.921 B	30
31	0.583 B		0.602 B		1.18		0.433	0.341		0.821 B		0.731 B	31
TOTAL	20.493	17.550	20.335	23.412	36.977	29.677	13.349	8.401	13.589	19.800	17.851	20.901	TOTAL
MEAN	0.661	0.605	0.656	0.780	1.19	0.989	0.431	0.271	0.453	0.639	0.595	0.674	MEAN
DAM3	1770	1520	1760	2020	3190	2560	1150	726	1170	1710	1540	1810	DAM3
MAX	0.778	0.957	0.940	1.95	1.82	2.10	1.66	0.507	0.816	0.965	0.808	0.951	MAX
MIN	0.488	0.492	0.456	0.400	0.538	0.320	0.122	0.071	0.015	0.430	0.361	0.087	MIN

SUMMARY FOR THE MONTHS JAN TO DEC
MEAN DISCHARGE,0.662 M3/S
TOTAL DISCHARGE, 20900 DAM3
MAXIMUM DAILY DISCHARGE, 2.10 M3/S ON JUN 29
MINIMUM DAILY DISCHARGE,0.015 M3/S ON SEP 26

MAXIMUM INSTANTANEOUS DISCHARGE, 3.22 M3/S AT 1629 CST ON JULY 04

A-MANUAL GAUGE
B-ICE CONDITIONS

C-15

WATER SURVEY OF CANADA
MAY 1 1985 PAGE 7
REGINA, SASK.

BIRCH RIVER MARSH NEAR CUMBERLAND HOUSE

STATION NO. 05KH014

(PRELIMINARY) DAILY WATER LEVEL IN METRES FOR 1984

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	263.891	263.977 E	263.988	264.034	263.990	263.710	263.407	263.693	263.777	263.825	263.786	263.880	1
2	263.898	263.978 E	263.996	264.035	263.971	263.707	263.404	263.691	263.779	263.807	263.791	263.881	2
3	263.904	263.979 E	264.000	264.038	263.947	263.720	263.424	263.687	263.785	263.765	263.798	263.884	3
4	263.902	263.980 E	264.000	264.037	263.936	263.698	263.495	263.685	263.788	263.723	263.801	263.886	4
5	263.904	263.981 E	263.995	264.044	263.927	263.636	263.521	263.683	263.789	263.697	263.806	263.886	5
6	263.903	263.983 E	263.993 A	264.048	263.920	263.610	263.537	263.682	263.786	263.681	263.810	263.886	6
7	263.908	263.984 E	263.992 E	264.050	263.911	263.625	263.547	263.682	263.811	263.662	263.814	263.894	7
8	263.910 A	263.985 E	263.991 E	264.057	263.900	263.647	263.554	263.678	263.810	263.649	263.819	263.898	8
9	263.917 A	263.986 E	263.990 E	264.056	263.875	263.634	263.558	263.674	263.814	263.641	263.823	263.899	9
10	263.922 E	263.987 E	263.991 E	264.057	263.862	263.610	263.579	263.667	263.812	263.623	263.822	263.900	10
11	263.926 E	263.987 E	263.992 E	264.066	263.882	263.581	263.634	263.652	263.809	263.606	263.824	263.901	11
12	263.932 E	263.986 E	263.993 E	264.069	263.870	263.585	263.663	263.633	263.809	263.612	263.824	263.897	12
13	263.938 E	263.985 A	263.994 E	264.077	263.860	263.581	263.677	263.617	263.812	263.622	263.828	263.898	13
14	263.942 E	263.985	263.995 E	264.081	263.824	263.552	263.698	263.607	263.813	263.631	263.832	263.898	14
15	263.946 E	263.981	263.996 E	264.081	263.801	263.504	263.712	263.606	263.819	263.637	263.836	263.906	15
16	263.950 E	263.979	263.998 E	264.081	263.799	263.491	263.716	263.615	263.825	263.664	263.842	263.909	16
17	263.955 E	263.983	263.999 E	264.080	263.792	263.484	263.717	263.623	263.830	263.705	263.842	263.912	17
18	263.958 E	263.984	264.000 E	264.077	263.792	263.482	263.719	263.629	263.830	263.714	263.842	263.915	18
19	263.960 E	263.987	264.001 E	264.077	263.803	263.452	263.720	263.637	263.829	263.715	263.846	263.923	19
20	263.962 E	263.990	264.002 E	264.075	263.787	263.405	263.717	263.666	263.824	263.723	263.852	263.925	20
21	263.964 E	263.990	264.003 E	264.076	263.809	263.443	263.720	263.663	263.812	263.729	263.861	263.933	21
22	263.966 E	263.990	264.002 E	264.073	263.817	263.449	263.722	263.668	263.818	263.730	263.863	263.932	22
23	263.968 E	263.989	264.001 A	264.074	263.817	263.447	263.719	263.670	263.833	263.735	263.866	263.934	23
24	263.969 E	263.988	263.996	264.066	263.805	263.431	263.716	263.685	263.833	263.738	263.871	263.937	24
25	263.970 E	263.989	264.005	264.042	263.804	263.413	263.714	263.701	263.834	263.738	263.873	263.942	25
26	263.971 E	263.992	264.025	264.028	263.792	263.405	263.712	263.716	263.835	263.746	263.877	263.936	26
27	263.972 E	263.994	264.029	264.013	263.780	263.383	263.711	263.721	263.834	263.754	263.879	263.946	27
28	263.973 E	263.988	264.027	264.017	263.763	263.369	263.706	263.738	263.832	263.760	263.878	263.954	28
29	263.974 E	263.988	264.027	264.016	263.749	263.399	263.703	263.755	263.829	263.768	263.879	263.954	29
30	263.975 E		264.030	264.000	263.747	263.408	263.701	263.767	263.826	263.777	263.880	263.960	30
31	263.976 E		264.031		263.740		263.697	263.771		263.782		263.963	31
TOTAL	8182.206	7655.575	8184.082	7921.625	8179.072	7905.861	8172.820	8173.962	7914.437	8174.959	7915.165	8181.369	TOTAL
MEAN	263.942	263.985	264.003	264.054	263.841	263.529	263.639	263.676	263.815	263.708	263.839	263.915	MEAN
MAX	263.976	263.994	264.031	264.081	263.990	263.720	263.722	263.771	263.835	263.825	263.880	263.963	MAX
MIN	263.891	263.977	263.988	264.000	263.740	263.369	263.404	263.606	263.777	263.606	263.786	263.880	MIN

SUMMARY FOR THE YEAR 1984

MAXIMUM DAILY WATER LEVEL, 264.081 METRES ON APR 14

MINIMUM DAILY WATER LEVEL, 263.369 METRES ON JUN 28
MAXIMUM INSTANTANEOUS WATER LEVEL, 264.084 METRES AT 1923 CST ON APRIL 17
WATER LEVELS ARE REFERRED TO GSC DATUM
ADD 260.522 METRES TO CONVERT TO DUCKS UNLIMITED EXTENSION

A-MANUAL GAUGE

E-ESTIMATED

WATER SURVEY OF CANADA
MAY 12 1980
REGINA, SASK

DRAGLINE CHANNEL NEAR SQUAW RAPIDS
OSKHOLI
1978

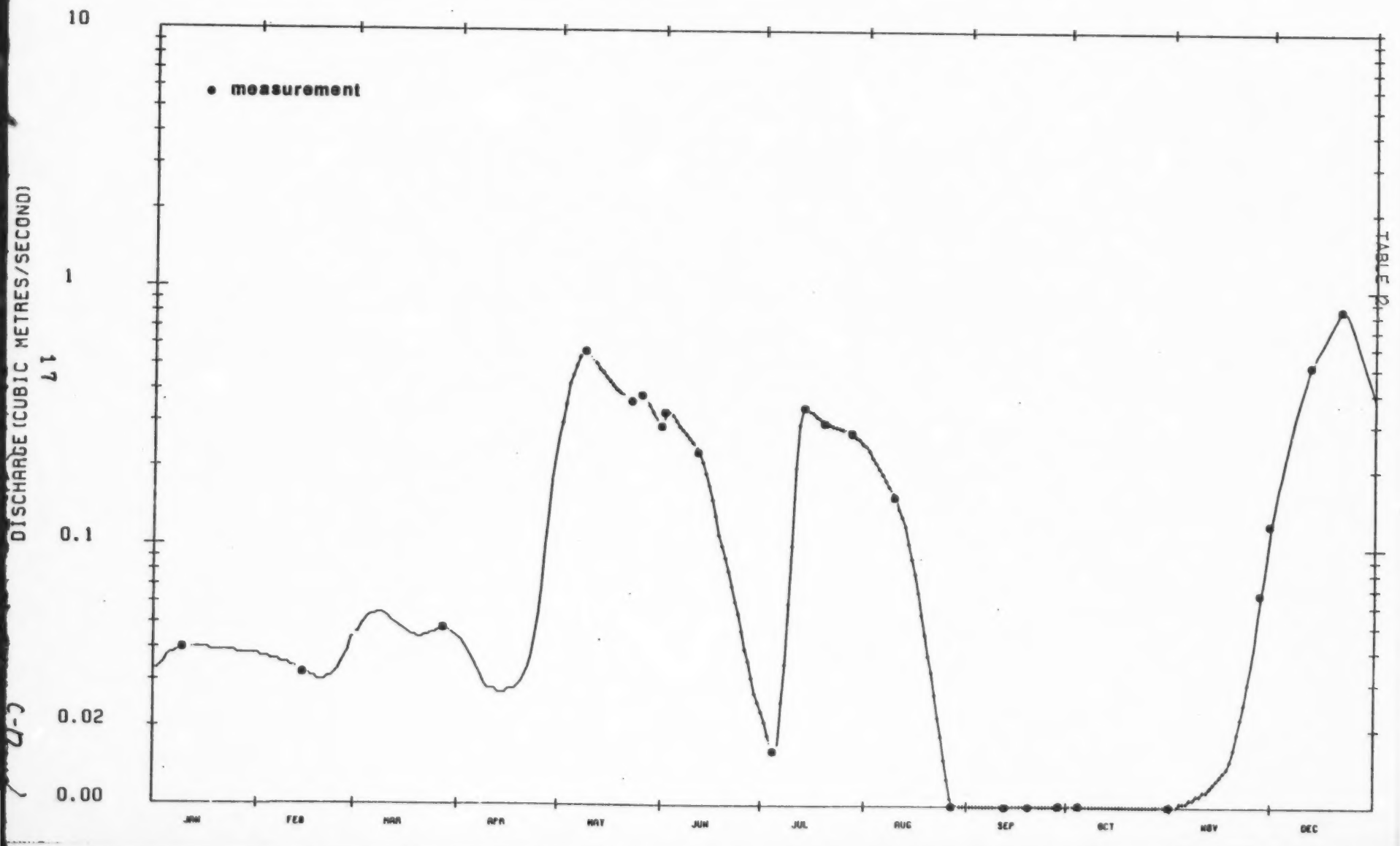
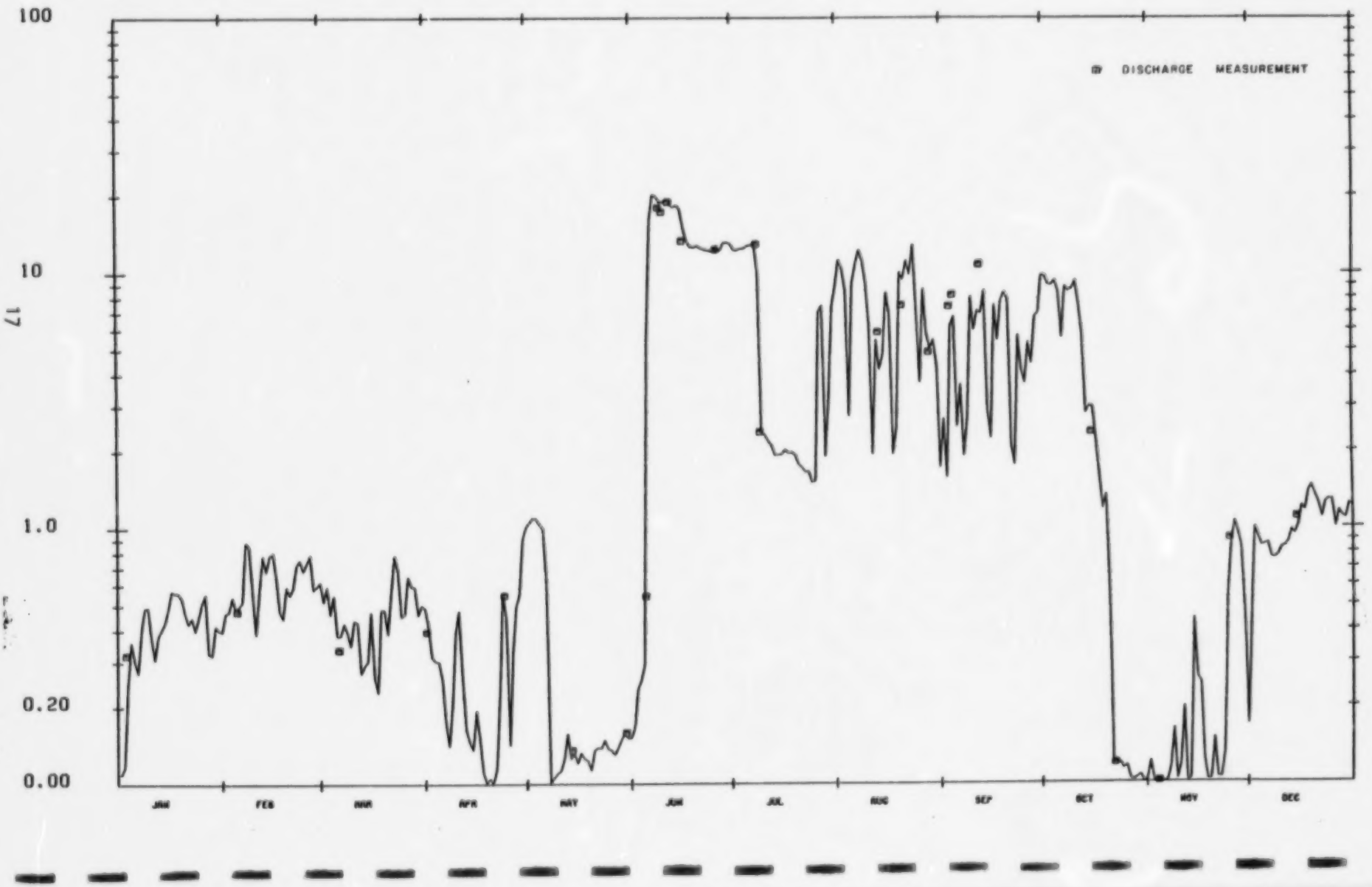


TABLE 21

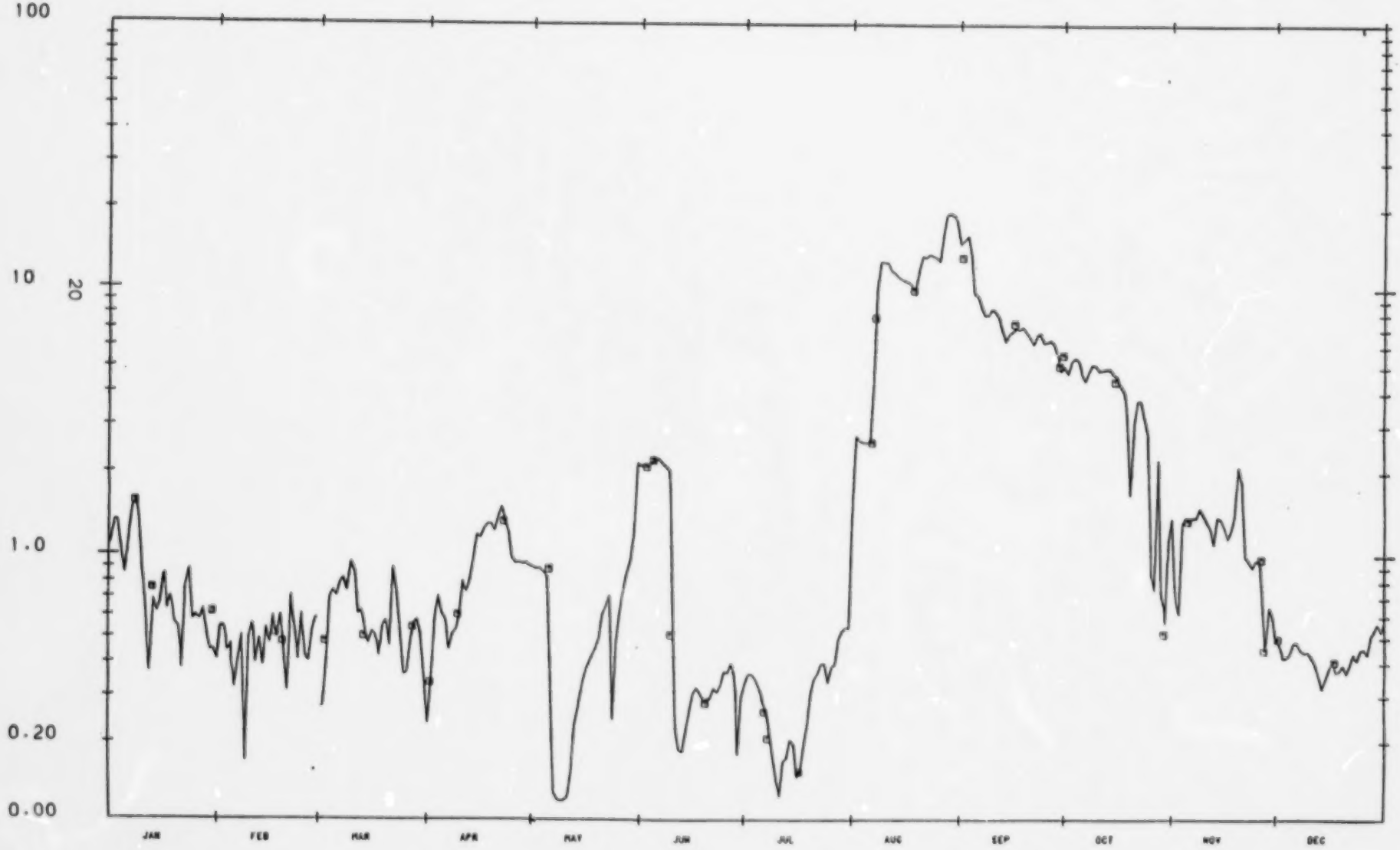
WATER SURVEY OF CANADA
FEB 18 1981
REGINA, SASK

DRAGLINE CHANNEL NEAR SQUAW RAPIDS
OSKNOSI
1980



WATER SURVEY OF CANADA
MAR 02 1981
REGINA, SASK

DRAGLINE CHANNEL NEAR SQUAW RAPIDS
05KH011
1981

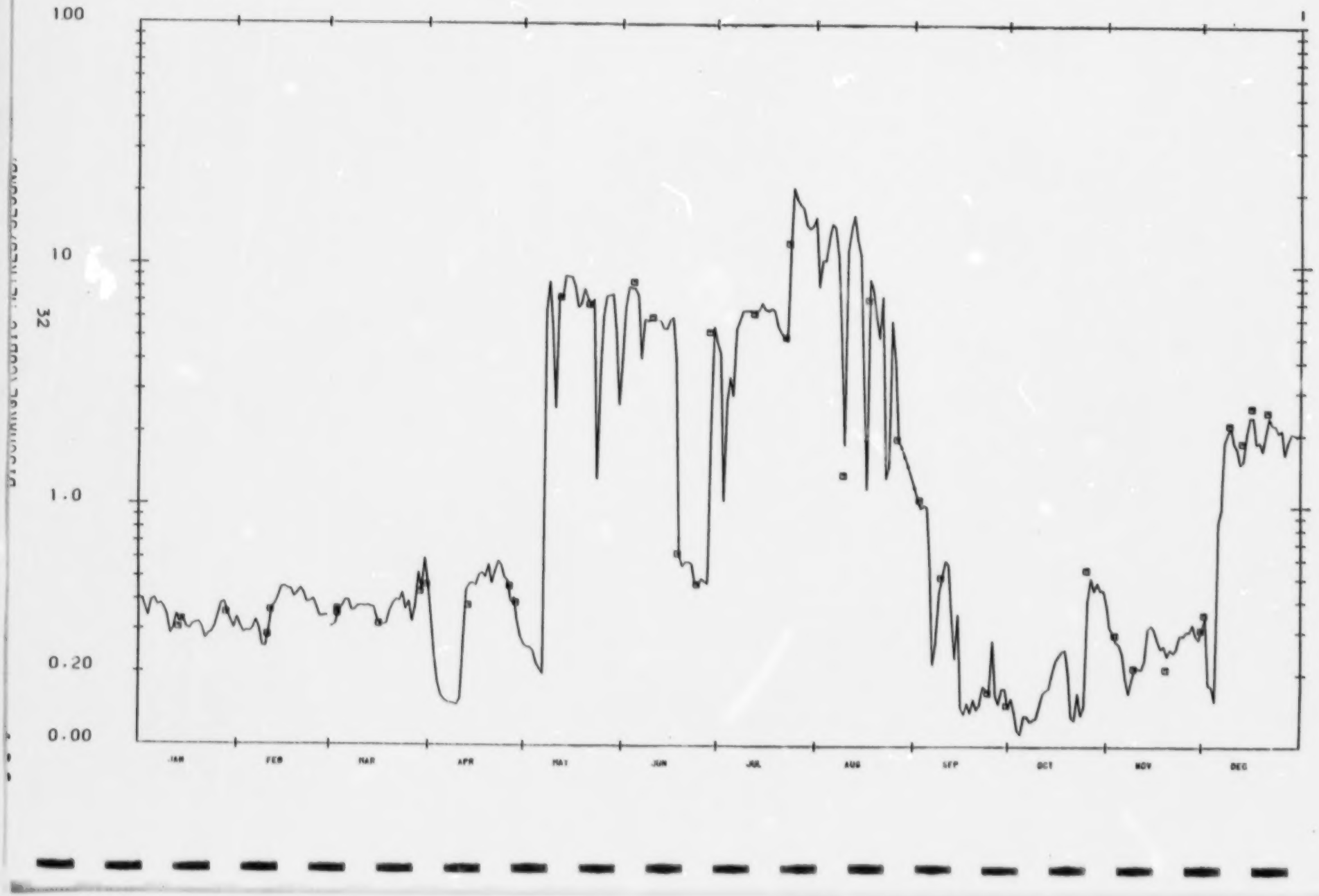


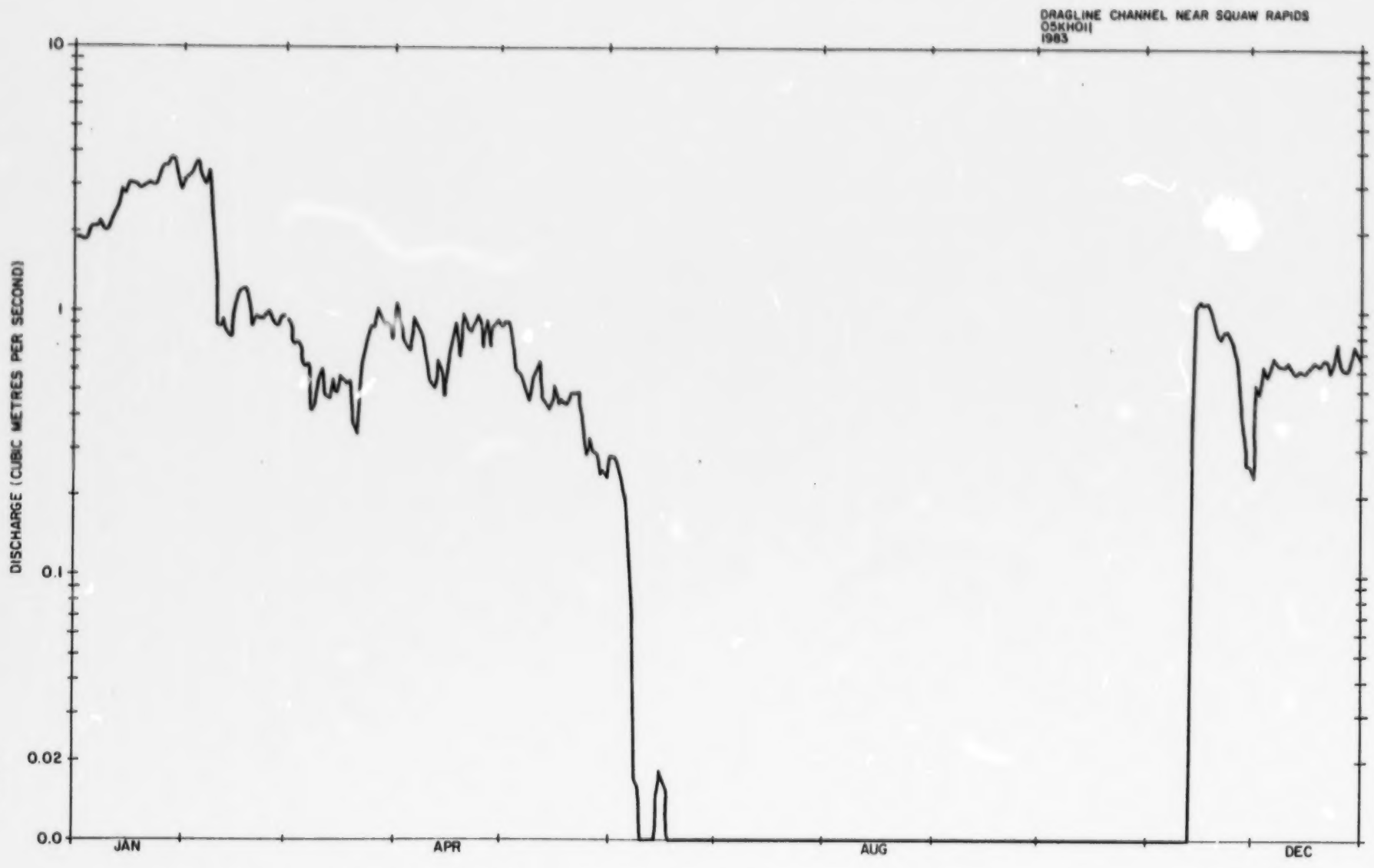
DISCHARGE (CUBIC METRES/SECOND)

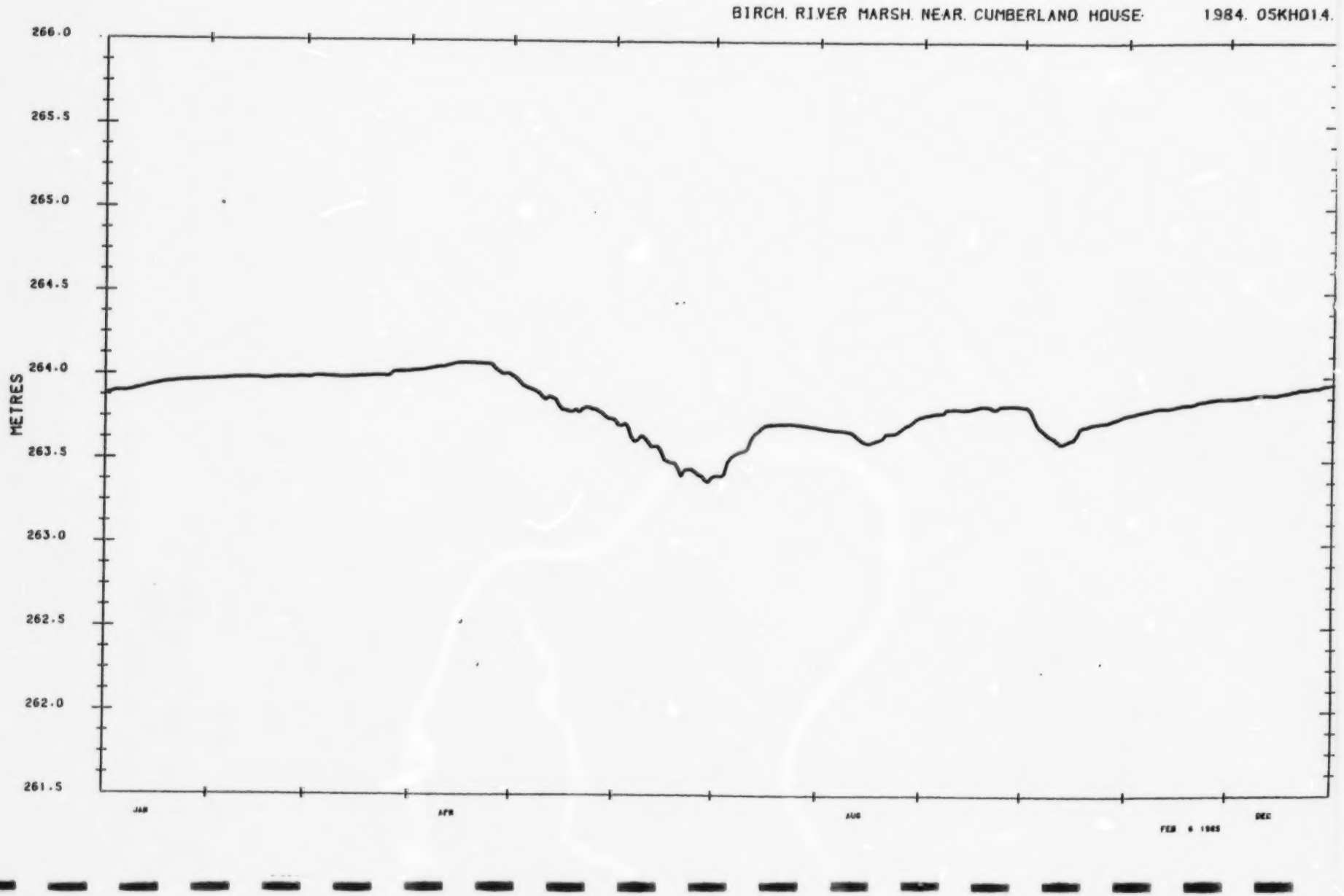
61-7

WATER SURVEY OF CANADA
MAR 29 1983
REGINA, SASK

DRAGLINE CHANNEL NEAR SQUAW RAPIDS
05KH011
1982

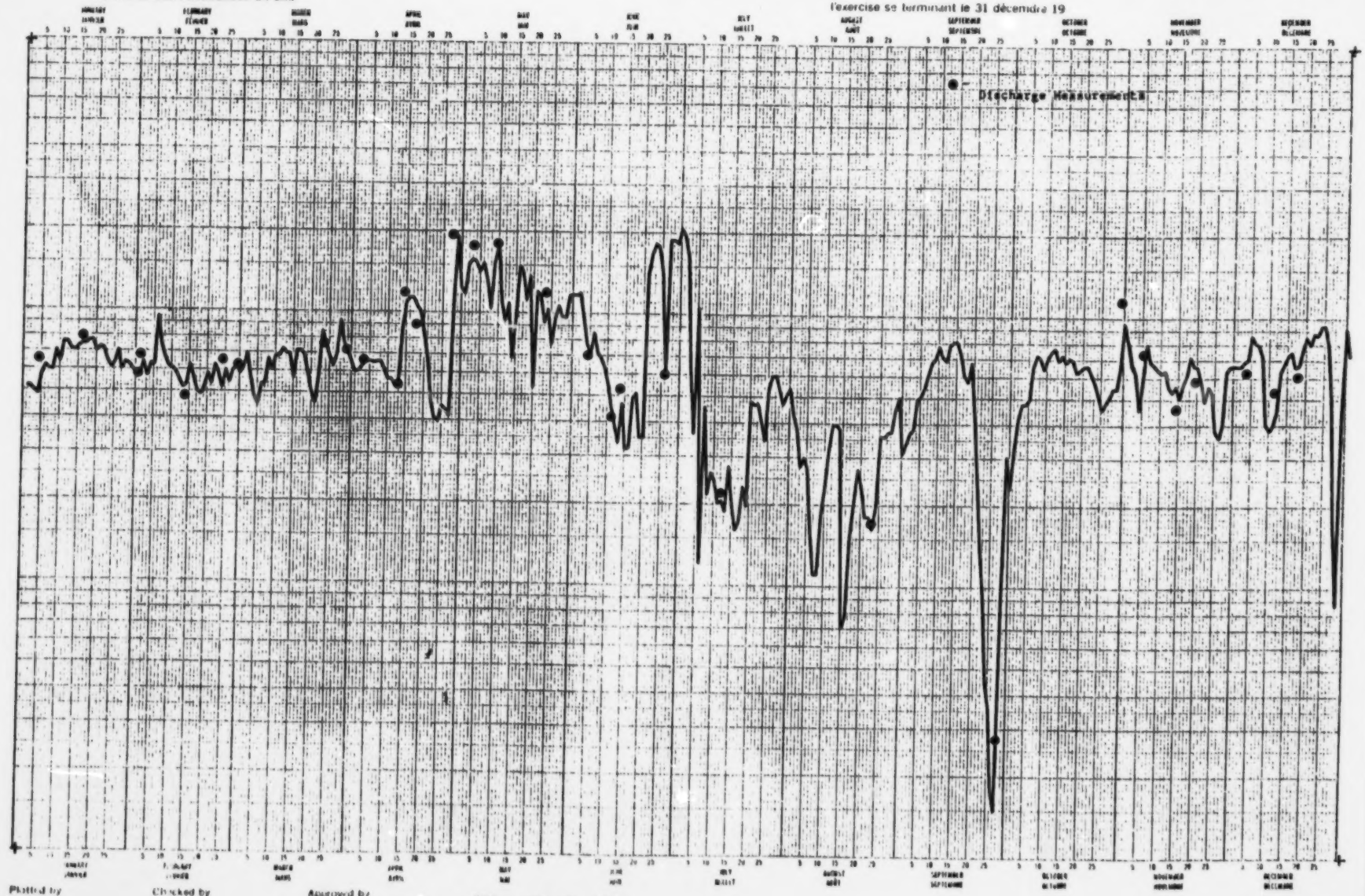



DRAGLINE CHANNEL NEAR SQUAW RAPIDS
05KH011
1983
DISCHARGE (CUBIC METRES PER SECOND)
10
1
0.1
0.02
0.0
JAN
APR
AUG
DEC


BIRCH RIVER MARSH NEAR CUMBERLAND HOUSE 1984. 05KH014.
266.0
265.5
265.0
264.5
264.0
263.5
263.0
262.5
262.0
261.5
METRES
JAN
APR
AUG
DEC
FEB 6 1985

DEPARTMENT OF THE ENVIRONMENT
MINISTÈRE DE L'ENVIRONNEMENT
WATER RESOURCES BRANCH
DIRECTION DES RESSOURCES EN EAU

HYDROGRAPH FOR DRAGLINE CHANNEL NEAR SQUAW RAPIDS Station No. 05KH011.
HYDROGRAMME POUR _____ No de la Station _____
for year ending December 31, 19 84.
l'exercise se terminant le 31 décembre 19



Plotted by
Tracé par

Checked by
Vérifié par

Approved by
Approuvé par

Date MAR 23 1985

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